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THE SOUTH AFRICAN (CAPE) FUR SEAL

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On the cover: The South African (Cape) fur seal, *Arctocephalus pusillus pusillus* (photograph by P. Wickens).

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Trawling Operations and South African (Cape) Fur Seals, *Arctocephalus pusillus pusillus*

PATTI A. WICKENS and PETER F. SIMS

Introduction

The incidental take of marine mammals during trawl operations has received attention in several countries, including South Africa (Shaughnessy and Payne, 1979), Alaska (Perez and Loughlin, 1991), Canada (Pemberton et al., 1994), and New Zealand (Mattlin and Cawthorn, 1991). Less common are analyses of the losses to trawl fisheries through interaction with marine mammals, although in South Africa this has been documented and discussed (Shaughnessy, 1985; David, 1987; Wickens, 1989; Wickens et al., 1992). Such research has also revolved around the extent of consumption of fish discarded by trawlers and the possibility that trawler offal supports the needs of part of the population (David, 1987; Wickens et al., 1992), but not on cost of the losses from different fisheries. All studies of operational interactions between seals and the trawl fishery in South Africa (Rand, 1959; Shaughnessy and Payne, 1979; Shaughnessy, 1985; Ryan and Moloney, 1988; Anonymous, 1987; Wickens, 1989; Wickens et al., 1992) have focussed on the number of seals attending trawling operations and the numbers entrapped in the nets, and almost all have dealt with offshore demersal trawling only. Wickens et al. (1992) reviewed research on all seal-fisheries operational interactions in South Africa, and this was followed by an evaluation of these interactions in South Africa (Wickens, 1993, 1994). Based on that study, this paper evaluates the operational interactions between seals and each of the three trawl fisheries (offshore demersal, inshore demersal, and midwater) separately, in terms of financial cost to the industry (from catch losses, gear damage, and operational disturbance) and mortality or injury to the seals (through incidental and deliberate killing) in South African waters. This is done by evaluating new data and by making comparisons with published studies.

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ABSTRACT—South African (Cape) fur seals, Arctocephalus pusillus pusillus, *interact with the South African trawl fisheries—offshore demersal, inshore demersal, and midwater fisheries. These interactions take the following forms: Seals take or damage netted fish, on particular vessels they become caught in the propeller, seals drown in the nets, live seals come aboard and may be killed. Except in specific cases of seals damaging particular trawler propellers, interactions result in little cost to the offshore and midwater trawl fisheries. For the inshore fishery, seals damage fish in the net at an estimated cost in excess of R69,728 (US\$18,827) per year, but this is negligible (0.3%) in terms of the value of the fishery. Seal mortality is mainly caused by drowning in trawl nets and ranges from 2,524 to 3,636 seals of both sexes per year. Between 312 and 567 seals are deliberately killed annually, but this most likely takes place only when caught and they enter the area below deck, where they are difficult to remove, and pose a potential threat to crew safety. Overall, seal mortality during trawling operations is negligible (0.4–0.6%) in terms of the feeding population of seals in South Africa.*

The South African (Cape) fur seal, *Arctocephalus pusillus pusillus,* is the only breeding pinniped found in southern Africa. This species, with a population size of up to 2 million seals (Anonymous, 1991), constitutes one of the largest fur seal populations in the world (Croxall and Gentry, 1987). Over one-third of the total population ranges along the South African coastline (Wickens et al., 1991), the area considered in this study, while the remainder is found off the Namibian coast. Off South Africa, seals are found at 10 breeding colonies and 5 nonbreeding colonies (where pups are found only on an irregular basis). The largest and only mainland colony is Kleinsee, where two-thirds of the pups in South Africa are born (Wickens et al., 1991). Between 1985 and prior to the cessation of sealing in 1990, this was the only colony at which sealing occurred (Wickens et al., 1991).

In South Africa, the trawl fishery is the second largest contributor, after the pelagic purse-seine fishery (28%, an average of 172,000 metric tons (t) annually between 1988 and 1992 inclusive), to the South African fishing industry in terms of the cleaned (mainly headed and gutted) mass of fish landed. However, it is by far the largest (51%, an average of R260 million or US\$74 million) in terms of financial value to the industry (data from Sea Fisheries, Cape Town). Within the fishing industry this sector involves the largest number of personnel (almost 9,000), one-third of whom are fishermen operating on trawlers.

The trawl sector is divided into offshore and inshore demersal trawling

and, since 1989, midwater trawling (Fig. 1). Prior to 1991 there was also an experimental demersal longline fishery. During that longlining, an estimated 5.3% of the catch was lost to seals (Wickens et al., 1992), and this was considered a significant quantity. Offshore demersal trawling provides by far the greatest landed mass and landed value of fish. The masses of fish landed by the inshore demersal and midwater trawl sectors are similar, but the value of the inshore trawled fish is greater.

Offshore demersal trawling targets the two species of Cape hake, *Merluccius capensis* and *M. paradoxus*, for which there is a single total allowable catch; kingklip, *Genypterus capensis*, is caught as a by-catch (Payne, 1989). In 1992 there were 58 active offshore trawlers which generally fish only by day. Most are stern trawlers and a few are side trawlers.

Inshore demersal trawling targets hake and the Agulhas sole, *Austroglossus pectoralis*, for which there are species-specific total allowable catches (Payne and Badenhorst, 1989). Kingklip is a by-catch, as in the offshore trawl fishery. This form of trawling is done with side trawlers, both day and night. In 1992 there were 37 trawlers actively used for inshore trawling.

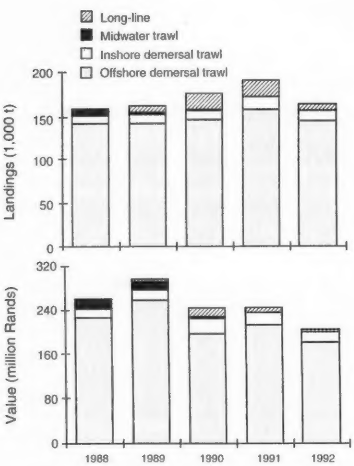

Figure 1.—Contribution of the sectors within the trawl and demersal longline fisheries in South Africa in terms of landings and landed value over a 5-year period (1988–92).

Midwater trawling targets mainly Cape horse mackerel, *Trachurus trachurus capensis* (Crawford, 1989). There is no total allowable catch, but to place some limitation on the exploitation of this species, a maximum annual catch is recommended. In 1992 there were seven vessels, all stern trawlers, licensed for midwater trawling, but most were not exclusively involved in midwater trawling. Midwater trawling is done mainly at night.

Data Collection

Quantitative information through independent surveys was required in which observers record counts of seals and incidences of entrapment during trawling operations aboard commercial vessels. Observers were briefed before leaving, the completed data sheets were examined on their return, and any unusual occurrences were cross-checked. Independent observations were possible on offshore trawlers, but there were logistical difficulties in carrying out independent observations at sea on inshore demersal and midwater trawlers.

Observations of offshore and inshore demersal trawling were made from both commercial and research trawlers, but the data from the two types of vessel are not directly comparable. The research vessel was a stern trawler which trawled for a period of 30 minutes, a shorter trawl time than done by commercial vessels. Research trawls were made using a net with a 27 mm (10.6-inch) mesh liner as opposed to minimum commercial net mesh restrictions of 110 mm (43.3 inches) and 75 mm (29.5 inches) to the west and east of Cape Agulhas, respectively. The two sets of data were analyzed separately, with the research data being used for comparison only.

During 1992 observers made nine demersal offshore trawling trips on commercial vessels, all but one of which were on stern trawlers (Table 1). The observation period totaled some 64 days at sea, during which about 600 t of cleaned (mainly headed and gutted) fish were caught. Observations were made during 222 hauls of the net. A further 75 days of observation took place on

Table 1.—Details of commercial and research trips undertaken to observe seal interactions during trawling operations during 1992–93. Observations on the offshore and inshore trawlers were done by independent observers and those on the midwater trawler by the skipper.

Trip and vessel	Company	Month	Duration (days)	Observed hauls
Offshore demersal				
Commercial		Jan.-July	64	222
1. Anemone	I & J[1]	Jan.	9	26
2. Harvest Galaxy	Sea Harvest	Feb.	6	30
3. Erica	I & J	Feb.	10	36
4. Aloe	I & J	Apr.	4	15
5. Harvest Belinda	Sea Harvest	Apr.	5	21
6. Begonia	I & J	May	7	23
7. Aloe	I & J	June	6	18
8. Aloe	I & J	July	7	21
9. Begonia	I & J	July	10	32
Research		Feb.-April	75	132
1. Africana		Feb.	25	17
2. Africana		April	25	30
3. Africana		Feb.	25	84
Total (12 trips)			139	354
Inshore demersal				
Commercial		Jan.-July	27	65
1. Atlantic Privateer	Mariette Fishing	Jan.	2	3
2. F.V. Immanuel	Mariette Fishing	March	6	17
3. Atlantic Privateer	Mariette Fishing	May	6	22
4. Dunevegan	Mariette Fishing	Jan.	3	5
5. Barcelona	P. Cronje	Feb.	6	13
6. Mary Ann	P. Cronje	July	4	5
Research		April-Sept.	75	72
1. Africana		April	25	43
2. Africana		Sept.	25	29
Total (8 trips)			102	137
Midwater				
Commercial		June-July	21	16
1. Roxana Bank	I & J	June-July	21	16

[1] Irvin & Johnson

the research vessel *F.R.S. Africana* in 1992 and 1993, during which 131 offshore demersal hauls were observed.

Six inshore demersal trawling trips were undertaken in 1992 and 1994 (Table 1). During the 27 days spent at sea, a catch of approximately 44 t of cleaned fish were caught on 65 hauls, all of which were observed. Conditions aboard inshore trawlers did not readily allow for accommodation of additional personnel as observers. Hence, the number of observed commercial hauls was limited. During 50 days at sea on two research cruises on *F.R.S. Africana* during 1992, records of seal activity were made during 72 inshore demersal hauls.

As a result of the difficulties involved in obtaining observations from commercial inshore trawlers and the fact that damaged fish are not sorted at sea, a monitoring program was established to record seal-damaged fish in the catches at landing sites. This took place at the Irvin and Johnson (I & J) and Sea Harvest[1] factories in Mossel Bay, the major landing site for inshore trawlers. Estimates of damaged fish and total landings were recorded by the same two factory production supervisors at each factory from May 1992 to April 1994. These persons are not affiliated with the vessels from which the fish are landed and are therefore considered to be independent recorders. The mass of seal-damaged sole and seal-bitten kingklip was recorded from a total of 991 landings, during which time over 1,068 t of sole and over 133 t of kingklip were landed.

On the smaller midwater trawlers it was not possible to obtain a berth for an observer, and the larger vessels only make a few trips during which midwater trawling may take place. For this reason no independent observation data of seal interactions with the midwater trawl fishery were obtained. However, one of the larger trawling companies chose one of their skippers as an appropriate and reliable person for collecting data. Observations were made by this skipper as some indication of entrapment and deliberate killing during 16 hauls in 1993 (Table 1). A discussion and quantification of the interactions are also provided, based on the data collection from the offshore demersal trawl observations.

For all of the trawl fisheries, catches are expressed in terms of landed mass, and economic calculations are made using landed values from 1992, the latest available data from Sea Fisheries, South Africa. The South African currency of Rands is converted to U.S. dollars using an exchange rate of US$0.27:R1 as of July 1994. For later calculations, the total number of trawls during 1992 is used, and consisted of 42,374 offshore demersal trawls, 21,575 inshore demersal trawls, and 1,100 midwater trawls.

For discussion purposes, the South African coastline is divided into the "west" coast, defined as the region west of Cape Agulhas, and the "south" coast, the region east of Cape Agulhas (Fig. 2). Most offshore trawling takes place and most seal pups are born on the west coast, and likewise most observation effort is concentrated in this region, with less on the south coast. By contrast almost all fishing effort by inshore trawlers is concentrated on the south coast, and all of the observer effort was done in this area, mostly within 50 miles of Mossel Bay. Midwater trawling also takes place mostly on the south coast, with a small quantity being done on the west coast. In this region there are only two breeding colonies of seals but trawling activity is close inshore.

Offshore and inshore demersal trawling is carried out consistently throughout the year, and observations from commercial trawlers occurred during

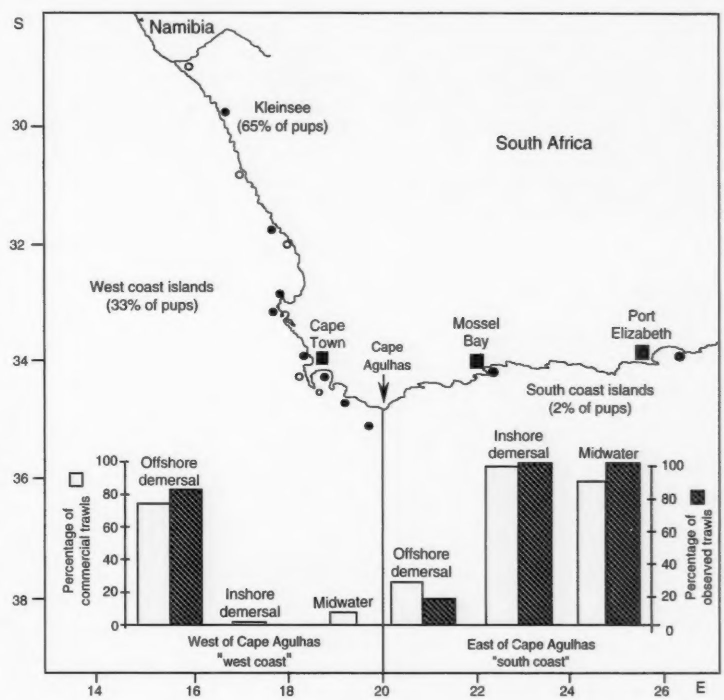

Figure 2.—Distribution of commercial (1992) and observed (1992–94) trawls for the offshore and inshore demersal and midwater trawl fisheries. The location of the breeding (dot) and non-breeding colonies (circle) of the South African (Cape) fur seal in South Africa are shown with the percentage of all pups born in South Africa for Kleinsee and the islands to the west and east of Cape Agulhas.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

the first half of the year when berths and observers were available. Midwater trawling also occurs through the year, but concentrated effort depends on the availability of fish and the allocated quotas. Observations of midwater trawling were made by the selected vessel at midyear.

Seal Attendance

Seal counts were made by observers at commercial offshore and inshore demersal hauls; they include seals around the trawler, i.e., not only at the stern or side where the net was hauled. No counts of seals were made during midwater trawling. Fish processing and discard release take place throughout the trawling process, so seal attendance includes seals that are feeding on such discards. For offshore trawlers it is assumed that the number of seals attending side trawls is the same as at stern trawls, so these data are combined.

The numbers of seals counted during different stages of the trawl are shown in Table 2. Seals are most likely to take fish from the time the net nears the surface until it is hauled aboard. The number of seals counted when the codend of the net surfaces is taken as the average number feeding. However, these counts of the actual number that may be pulling fish from the net are a minimum, because seals will also be feeding below the surface and will not be counted. Seals counted are likely to move between different trawlers working in an area, and therefore this number cannot be multiplied up by the number of trawlers to establish total numbers of seals feeding in an area.

Offshore Demersal Trawling

Seals were seen on the majority (>84%) of observed offshore demersal hauls and more frequently on the west coast. On both the west and south coasts, it was most common for observers to see ≤5 seals/haul, but on the west coast many more were also seen on occasion (Fig. 3). If the maximum number seen during a haul is considered, most observations were of 11–20 seals at a trawl on the west coast and fewer on the south coast. On 40% of the observed commercial trawls, other trawlers were visible and the seals seen by the observers were likely to move between these trawlers. The size of seals is difficult to estimate but only medium (40–100 kg; 88–220 pounds) and large (≥100 kg; ≥220 pounds) seals were reported. This was expected because young, small seals are less likely to feed far from the coast.

The following two points regarding offshore demersal trawling are noted, and both are postulated, based on our knowledge of seal distribution and behavior:

First, more seals attend offshore trawling operations on the west coast than on the south coast. On the south coast, offshore trawlers are restricted from trawling in water <110 m (<360 feet), and this includes the Agulhas Bank which extends 180 n. mi. offshore in places. On the west coast trawling takes place closer inshore and it is therefore more accessible to the seals. The observations show a mean of 18 seals (with a maximum of 260) on the west coast and a mean of 3 (with a maximum of 10) on the south coast; this difference is significant (Kruskal-Wallis test statistic = 35.7, $P<0.001$). Shaughnessy

Table 2.—Observed number of seals around offshore and inshore demersal trawlers during different stages of a trawl. No counts were made from midwater trawlers. The minimum count in each case was zero.

Stage of trawling operation	Number of seals observed: Mean ± 1 S.E.	Max.
Offshore demersal		
West coast		
Commercial (n = 185)		
Trawling (Shooting to net at depth)	4 ± 0.74	90
Start hauling net	15 ± 2.28	240
Otterboards on vessel	16 ± 2.13	260
Codend surfaces	18 ± 2.06	260
Net aboard	18 ± 1.84	200
Mean: Hauling to net aboard	16 ± 1.99	260
Research (n = 102)		
Codend surfaces	2 ± 0.40	30
South coast		
Commercial (n = 37)		
Trawling (Shooting to net at depth)	0 ± 0	1
Start hauling net	1 ± 0.16	5
Otterboards on vessel	2 ± 0.33	10
Codend surfaces	3 ± 0.33	8
Net aboard	3 ± 0.33	9
Mean: Hauling to aboard	2 ± 0.33	10
Research (n = 30)		
Codend surfaces	1 ± 0.37	6
Inshore demersal		
Commercial (n = 65)		
Trawling (Shooting to net at depth)	2 ± 0.52	22
Start hauling net	2 ± 0.39	15
Otterboards on vessel	4 ± 0.52	22
Codend surfaces	7 ± 0.77	27
Net aboard	10 ± 1.16	30
Mean: Hauling to aboard	6 ± 0.90	30
Research (n = 72)		
Codend surfaces	2 ± 0.24	10

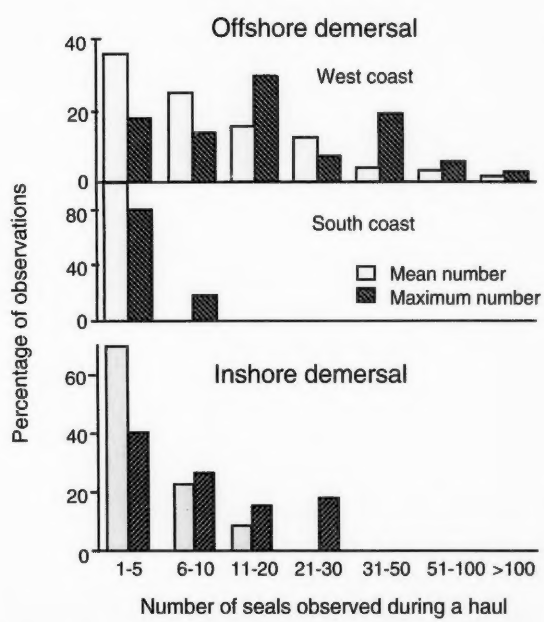

Figure 3.—Numbers of South African fur seals observed at offshore and inshore demersal trawling operations in South Africa.

and Payne (1979) recorded differences of a mean of 6 seals on the west coast and 4 on the south coast during commercial trawling. Data from research trawls indicate double the number of seals on the west coast (2 with a maximum of 30) compared to the south coast (1 with a maximum of 6). Other counts of seals from research trawls that have been documented are: on the west coast, 8 (Ryan and Moloney, 1988) and 10 (Shaughnessy and Payne, 1979); and, on the south coast, 3 seals (Shaughnessy and Payne, 1979). Fewer seals are seen at research trawls than commercial trawls. This is likely to be related to differences in trawl time, mesh size, and the fact that research trawls are made in random areas, often out of the commercial trawling grounds, with no regard for fish density, whereas commercial trawls seek to operate in areas with fish concentrations.

Second, many seals arrive only when the hauling starts. Indeed, seals may be attracted to the trawlers by the sound of the winch starting to haul the net. Current data confirm this, in that there is a significantly greater number of seals present from the time the net starts being hauled until it is aboard compared to when the vessel is trawling (Wilcoxon test statistic using ranks = 0.14 for the west coast and 4.92 for the south coast, $P<0.001$). On the west coast, there was a fourfold difference between these stages of the operation (from 4 to 16 seals), and on the south coast, numbers changed from no seals to an average of 2 seals.

Inshore Demersal Trawling

Seals were seen on the majority (95%) of inshore demersal hauls observed, and in two-thirds of the observed hauls the mean number seen was no more than five (Fig. 3). In terms of the maximum number of seals recorded during any haul, on over one-third of the hauls there were 1-5 seals, and on just more than one-fifth of the hauls there were 21–30 seals per haul. As during offshore trawling, seals are likely to move between trawlers working in an area, and an average of six trawlers were visible at every haul. Estimates of the size of seals indicated that mostly medium (40–100 kg; 88–220 pounds) and large (≥100 kg; ≥ 220 pounds) seals were reported, although a few small (<40 kg; 88 pounds) seals were also seen. It is probable that the presence of small seals results from the proximity of trawlers to the coast, where younger seals are found.

As with offshore trawling, significantly more seals accompany the inshore trawlers from the time the net starts being hauled than when the vessel is trawling (Wilcoxon test statistic = 5.29, $P<0.001$). The mean number seen before the net is hauled is 2 seals (with a maximum recorded of 22), whereas the mean number seen when the codend surfaces is 9 (with a maximum of 27 seals). By comparison, on research trawls the mean was 2 seals with a maximum of 10 when the codend surfaced.

Feeding

Seals were seen taking fish sticking through the net and scavenging moribund fish that floated free of the net (Fig. 4). Damaged fish are separated on board, but it is not possible to determine how much of the damage was attributable solely to seals. Damage to fish, and in particular to offshore trawled fish, also results from constriction of the net and the pressure of the fish mass, particularly during hauling.

The duration of each stage of a trawl was recorded during all commercial trawls (Table 3). The time from the net surfacing to its being hauled aboard is the minimum period during which seals may feed from the net. Seals may feed from the net while it is being brought to the surface, and they also feed on floating fish or discarded fish once the net has been hauled.

Offshore Demersal Trawling

In offshore side trawling, the net, or part of it, lies on the surface longer at the end of a haul than in offshore stern trawling. In offshore trawling this period averages 18 minutes for side trawls and 5 minutes for stern trawls. Commercial trawling effort is measured in hours (from the net reaching depth to start of hauling), and in 1992 a total of 92,602 hours was spent offshore trawling during 42,374 hauls. This results in an average trawl time of 2.2 hours. The time of 2.1 hours observed from the net depth to the start of hauling, as recorded from observations (Table 3), therefore indicates that the observed trawls were probably typical of offshore trawling. While seals may eat large quantities of fish near the net (one seal was observed eating 24 free-floating fish), fish damage attributable to seals in offshore-trawled catches is considered negligible.

Inshore Demersal Trawling

During inshore trawling, the average time period that seals have to feed on fish in the net when the codend lies on the sea surface is 8 minutes, although a maximum of 25 minutes was also recorded. This commercial trawling effort is also measured in hours (from the net reaching depth to start of hauling) and a total of 77,425 hours was spent inshore trawling in 1992 during 21,575 hauls. This produced an average trawl time of 3.6 hours. The time of 3.5 hours from the net at depth to the start of hauling as recorded from observations therefore indicates that the observed trawls were probably typical of inshore trawls.

Records of damaged fish made at the factories show that a greater proportion of kingklip is damaged than sole (Fig. 5). This is most likely to be at least partially attributable to the fact that sole can be pulled through the net easily and in this way can be removed whole (and therefore are not recorded in the catch), whereas seals can only bite those parts of kingklip that protrude through the net.

Spoilage of sole and kingklip by seals is not significantly correlated to monthly sole and kingklip landings, respectively (r[sole] = 0.359, r[kingklip] = 0.445, n=12, $P > 0.05$) so the extent of spoilage is likely to be related to both the time that the codend stays on the surface and the number of seals attending each haul. In both cases the fish are trimmed to remove the damaged portion, and this results in some financial loss.

Damage to sole averaged 0.7%, varying between 0.3 and 1.3% of the landings per month with the lowest losses recorded during June, but the reason for the fluctuations are not clear. Sole are

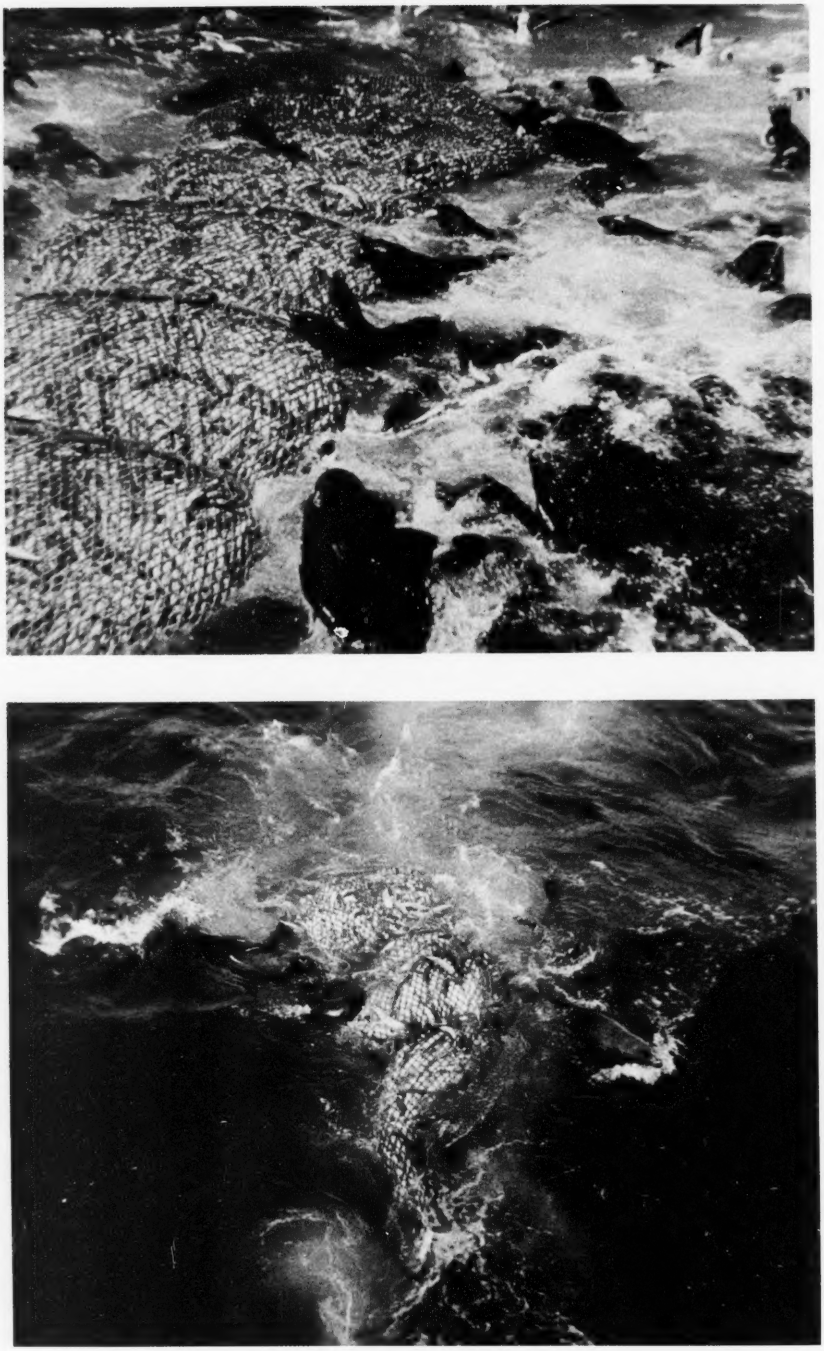

Figure 4.— South African fur seals feeding at an offshore demersal trawl net. Many seals mav feed from the net, particularly on the west coast of South Africa (top; photo by P. Bibb), however fewer are frequently seen (bottom; photo by J. Enticott).

Table 3.—Observed duration in minutes of different stages of offshore and inshore demersal trawls. The difference in the time taken between the codend reaching the surface and the net being aboard is given separately for stern and side offshore trawlers.

Stage of trawling operation	Duration (minutes) Mean ± 1 S.E.	Min.	Max.
Offshore demersal (n = 222)			
Shooting net –> net at depth	21 ± 0.47	3	60
Net at depth –> start hauling net	123 ± 2.62	37	305
Start hauling net –> doors on vessel	14 ± 0.47	5	70
Otterboards on vessel –> codend surfaces	5 ± 0.20	1	34
Cod end on surface –> net aboard (stern, n = 192)	5 ± 0.22	1	15
Cod end on surface –> net aboard (side, n = 30)	18 ± 1.28	10	43
Total : Start hauling to net aboard	25 ± 0.74	2	85
Total : Duration of trawl	171 ± 2.89	74	372
Inshore demersal (n = 65)			
Shooting net –> net at depth	9 ± 0.39	1	15
Net at depth –> start hauling net	210 ± 7.62	110	335
Start hauling net –> doors on vessel	10 ± 0.39	5	15
Otterboards on vessel –> codend surfaces	6 ± 0.26	3	15
Cod end on surface –> net aboard	8 ± 0.65	4	25
Total : Start hauling to net aboard	23 ± 0.90	15	45
Total : Duration of trawl	242 ± 7.36	140	359

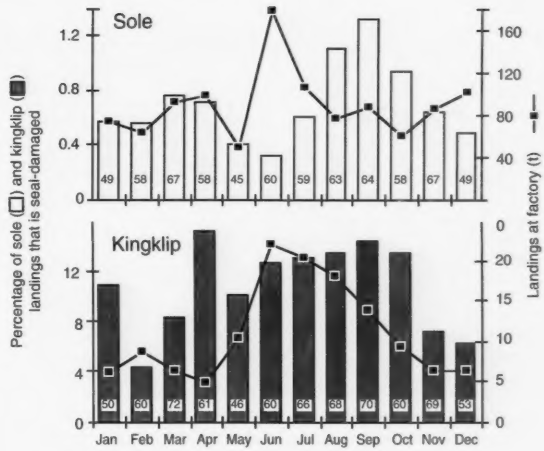

Figure 5.—Monthly inshore demersal trawl landings and the quantities of sole and kingklip that are seal–damaged, as recorded from two factories in Mossel Bay during this study. The numbers indicate the number of landings examined.

most commonly marketed with the head on, so seal-damaged fish which may be missing a portion of the body and head (Fig. 6a) are sold for a lower price per unit mass. The reduction in price of a damaged fish depends on the initial size of the fish, because prices per fish are size-dependent. On average, sole were considered to be reduced in price by 50%, although the vessels sometimes kept the seal-damaged sole to sell elsewhere at a higher price. At least 5.6 t (0.7%) from the 1992 landings (797 t) were estimated to be seal-damaged, although this is an underestimate because whole sole may be pulled from the net by seals and not recorded at the factory amongst the damaged fish. The landed price of sole in 1992 was R8.24 (US$2.22)/kg. If this damaged mass were sold at half price then the loss would be R23,072 (US$6,229).

Kingklip damage varied between 4.4 and 15.3% of the landings and was noticeably lower in February and November/December, but the reasons for this are not known. Kingklip is marketed in various forms so seal-damaged fish (Fig. 6b) is only regarded as a loss of mass, not a loss in the price per unit mass. For kingklip it is assumed that a third of the mass of each damaged fish is lost as a result of the seal bite and trimming. On average, 11.7% of the catch was damaged by seals which is a loss of 3.9% of the mass prior to landing. Although the 1992 landings were 200 t, the potential landing, if no seal damage had occurred, could have been 208.1 t, providing an estimate of damaged kingklip at 8.1 t. At the 1992 landed price of R5.76(US$1.56)/kg, some R46,656 (US$12,597) would be lost because of seals.

Overall the loss through seal depredation of sole and kingklip is calculated as R69,728 (US$18,827). This does not include fish that are pulled through the net mesh by seals and lost (particularly in the case of sole which can be pulled from the net whole), damage to other species, or damaged fish that are not landed. It can therefore be regarded as a minimum.

Midwater Trawling

Midwater trawls may last from about 10 minutes to a few hours, depending on depth and visibility of the fish; they averaged 2.6 hours during the observations in this study. The smaller mesh of the midwater trawl net means that less of the entrapped fish protrude, and they are therefore not easily accessible to seals. The larger catches made by midwater trawlers mean that proportionally less of the catch is available to the seals. Spoilage of fish is therefore considered to be negligible.

Equipment Damage

Net damage by seals is not generally considered to be a problem during any form of trawling. Observers did note, as a matter of course, the damage to fishing gear resulting from various causes, but only on an offshore trawler was minor net damage caused by a seal when it attempted to free itself from the net (0.5% of offshore trawls). Both offshore and inshore demersal nets were occasionally torn during observations, either from dragging on the bottom or from rocks that were brought up. The size of the tears varied, as did the time taken to repair them.

The propellers of some offshore demersal trawlers are mounted in Kort nozzles which increases suction. Seals feeding beside such vessels can be sucked into the nozzle and damage the propeller by bending or breaking off a part, and this may be costly. A trawler with a damaged propeller increases fuel consumption of the vessel, requires inspection by a diver, and may require repair or replacement. At least one-third of the vessels owned by the two major trawling companies are fitted with Kort

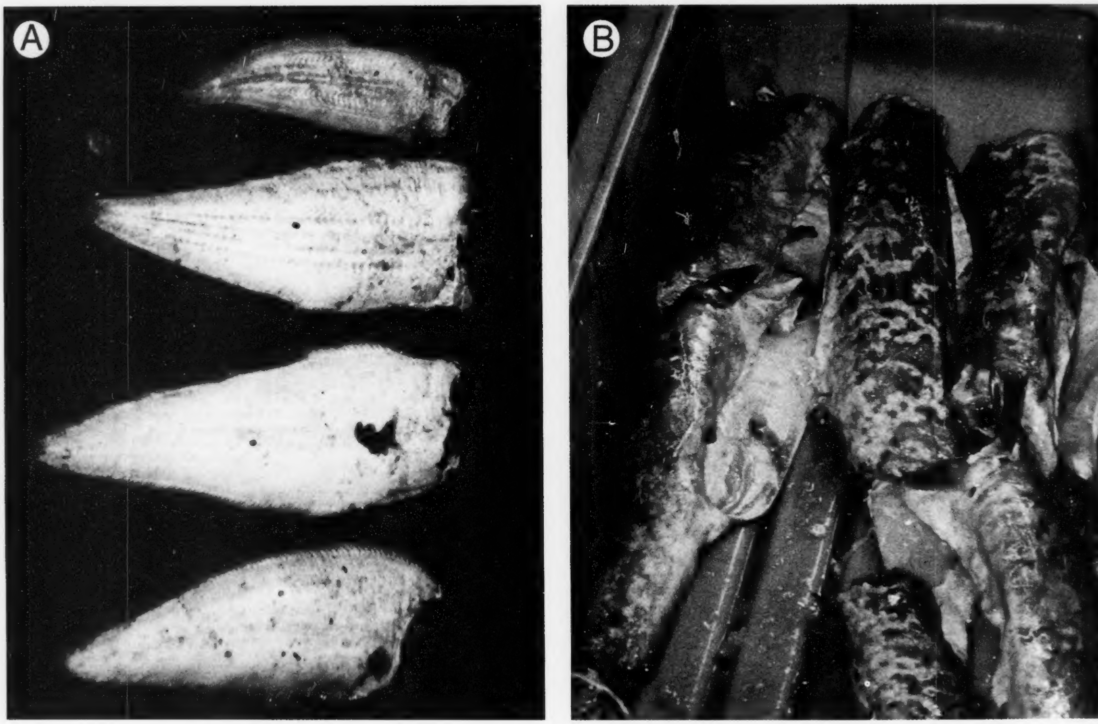

Figure 6.—Seal-damaged sole (a) and kingklip (b) from the inshore demersal fishery. Photo a by P. Sims and Photo b by L. Taylor.

nozzles, but few complaints of seals have been made by skippers. We suggest that problems may be related to the specific design of the vessel or to the position of the offal outlet at which seals may feed.

Two I & J trawlers, in particular, have reported such problems, and in 1991 both had the factory deck layout redesigned to move the outlet for discarded fish away from the propeller. In each case, the cost was about one million Rand (about US$250,000). However, the problem was not resolved and observers present during three trips on these vessels heard a thud and the engine straining as a seal passed through or became stuck in the nozzle. On some occasions there was blood in the water and injured seals surfaced. On one trip, the auxiliary power had to be brought in to complete the trawl and the main engine was then reversed to release a dead seal.

In late 1992, one of the I & J vessels which had problems with seals was fitted with a "crusher" to experiment with finely mincing the discarded fish so that it is less attractive for seals. In this way it is hoped that seals will not feed near the offal outlet and therefore will be less likely to be sucked into the nozzle. From the trials carried out to date, the experiment has proven successful.

Live Seals Aboard

Fishing operations may be disrupted if live seals are brought aboard in the net. Generally, returning live seals to the sea is not a problem and, from observations, in most instances the seals left the vessel of their own accord or were chased out by the crew. Most seals brought aboard do not go below deck, but when this happens it can be a problem. Nevertheless, injuries resulting from seals aboard trawlers are not common.

Offshore Demersal Trawling

During the 185 offshore demersal trawls observed on the west coast, there were 11 incidents (5.9% of hauls) in which live seals were brought aboard. In eight of these, one seal was involved, and in the remaining three there were two seals. These incidents involved a total of 14 seals, averaging 7.6 seals per 100 hauls. In two of the incidents a seal managed to get below deck (1.1% of hauls). In one case, fish boxes were placed strategically to provide the seal with an escape route and it climbed out and left the vessel after about 90 minutes (Fig. 7). In the other case, the seal became trapped in the factory area, and it was clubbed to death after removal attempts failed.

On the 37 observed south coast hauls there was one incident (2.7% of hauls average) of a single seal coming up in the net. The time taken for the seals on deck to leave the vessel generally varied from almost immediately to 45 minutes. An exceptional case was of a seal which was thought to be injured taking over 5 hours to leave, having been brought aboard during the last haul of the

Figure 7.—A seal caught in the hold of an offshore demersal trawler. In this case the crew placed fish boxes in the hold and the seal climbed out and left the vessel via the stern. Photo by J. Enticott.

day. No live seals were brought aboard during the 131 research trawls observed.

Based on the number of commercial trawls on the west coast (31,178) and the south coast (11,196) during 1992 and the observed percentage of times live seals were brought aboard in each area, a total of 2,672 seals are estimated to come aboard in a year (6.3 seals per 100 hauls). This is about 46/vessel annually. In comparison, Shaughnessy and Payne (1979) reported a seal brought aboard in 3.3% of trawls, i.e. 1,398 live seals brought aboard during the number of trawls made in 1992.

Inshore Demersal Trawling

Although no live seals were taken aboard during any of the inshore demersal trawls observed (commercial and research), they are known to get aboard but never to the areas below deck. Therefore they are hardly ever a problem to return to the sea.

Midwater Trawling

The mouth of a midwater trawl is wider than that of a demersal trawl, and consequently more seals are likely to be caught in the net than in other trawl nets. During the 16 midwater hauls observed by a skipper, there were a total of 20 live seals aboard in 10 of the hauls. This amounts to an occurrence of live seals on 63% of hauls or 693 incidences per year. This averaged 1.25 seals per midwater haul or 1,034 seals per year with a maximum of 4 seals in any one haul. Of these seals, 2 (10%) were killed because they entered the area below deck, making it difficult to remove them.

Incidental Seal Mortality or Injury

Incidental killing includes seals becoming caught in Kort nozzles and killed by the propeller as well as seals drowning in nets.

Offshore Demersal Trawling

On one observation trip on offshore trawlers, at least eight seals may have been killed by the propeller, as identified by blood in the water and the straining of the engines as the seals were entrapped.

During offshore demersal trawling, seals drowned in the nets on the west coast only. In total, 3 drowned in 185 hauls, or 1.6 seals per 100 hauls. In each case it was a single seal per haul, two of the seals being female and one male, ranging in size from 1.4 to 1.7 m. The three drownings took place on clear days and were in different areas; the carcasses were dumped overboard. In New Zealand, seals drown predominantly during night trawling (Anonymous, 1990).

Based on the annual number of offshore demersal hauls in each area, the total number of drownings would be 498 per year, possibly in the ratio of 332 females to 166 males, an overall average of 1.2 seals per 100 hauls. By comparison, one seal of unknown sex was drowned during research trawls on the west coast, i.e., 0.8 seals per 100 hauls. Shaughnessy and Payne (1979) indicate a greater drowning frequency than observed during this study, namely 3.8 seals per 100 hauls (no sex differentiation is given), which totals 1,610 seals drowning per year based on the number of trawls during 1992.

Inshore Demersal Trawling

The only form of seal mortality observed on inshore demersal trawlers was through incidental drowning. While live seals brought aboard may be killed deliberately if considered a risk to the crew, there are no data on this. During observations, there were three incidents in which seals were drowned in nets, an average of 4.6 seals per 100 hauls. All were male and ranged in size between 1.2 and 1.4 m, and all three were caught during the day. The annual incidence of drownings, estimated from the total number of commercial hauls, was 992 seals, possibly all male.

Midwater Trawling

The wider opening of the midwater trawl net, as opposed to a bottom trawl net, allows more seals to be caught. The slower retrieval, lower buoyancy, and tendency to trawl until the net reaches the vessel mean that more seals drown than during bottom trawls. It is possible that, as a result of midwater trawls being done at night, more seals may be caught, as occurs in New Zealand (Anonymous, 1990).

During the trip on which the skipper recorded seal occurrences in 16 mid-

water hauls, there were a total of 15 drowned seals on 10 (63%) of the hauls, an average of 94 seals per 100 hauls. One or two seals were drowned during each of these 10 hauls.

During a limited set of previous observations, in all, 16 dead seals were observed in 4 commercial midwater trawls, averaging 4 per trawl (Wickens et al., 1992). On the *F.R.S. Africana*, large numbers of seals have been caught in pelagic research trawls at night, and on at least two occasions there have been incidents west of Cape Agulhas in which many seals were caught. On one day, in an 11-minute drag, 28 seals were drowned in the net. On another day, during a 20-minute drag, between 25 and 30 seals were caught, most of which were still alive. Those numbers of seals seen caught are, however, uncommon in pelagic research trawls.

Based on the number of drownings observed (0.94/trawl, for the skipper data, or from a select number of commercial hauls, 4/trawl), a probable number of 1,034 drowned seals, or a maximum estimate of 4,400 drownings per year, is likely. Midwater trawling is a relatively new fishing method, but mortality could increase if the midwater trawl fishery increased and if it expanded up the west coast where seals are more abundant.

Deliberate Seal Mortality or Injury

Deliberate killing may take place if live seals are brought on deck, cannot be removed, and are potentially harmful to the crew.

Offshore Demersal Trawling

On one occasion a male seal (which was trapped below deck) was deliberately killed by the crew because it may have injured a crew member. This occurred on the west coast and amounts to a seal being killed in 0.5% of west coast hauls, an average of one seal killed in 0.4% of all hauls. Based on the total number of offshore hauls in 1992 this is equivalent to 169 seals per year. Shaughnessy and Payne (1979) report a single deliberate killing per 100 offshore trawls (no sex given) or 424 per year based on the current number of hauls in 1992.

Inshore Demersal Trawling

No live seals were brought aboard during the 65 observed trawls. However, it may occur and the seals may then be killed.

Midwater Trawling

Based on the observations made by the skipper during 16 hauls, 2 seals went below deck and were killed by the crew. The sex of the seals was not recorded. This amounts to an occurrence of 10% of live seals aboard being killed, or 13 seals per 100 midwater hauls. Based on the 1992 number of midwater trawls, this would amount to 143 seals/year.

Summary of Interactions

The extent of the interactions between seals and the three trawl fisheries in South Africa differ (Table 4). In the offshore demersal trawl fishery, seals appear to cause few problems technically or financially. Some two-thirds of the offshore demersal catch is made on the west coast of South Africa where most of the seals are found. The average number of seals attending offshore trawling operations in this area is 18, but the average is even lower on the south coast. Propeller damage, which has in the past been costly, occurs on only a few vessels, and ways to allevi-

Table 4.—Summary of interactions that occur between seals and offshore and inshore bottom trawling and midwater trawling activities with estimates of cost to the fishery and seal mortality.

Item	Demersal trawling		Midwater trawling
	Offshore	Inshore	
Seal attendance around vessel			
Frequency	>84% of hauls	95% of hauls	
Mean	<18	<10	
Maximum	260	30	
Effect on fishery			
Fish spoilage	Negligible	>R69,728	Negligible [1]
Net damage (tears)			
Frequency	0.5% of hauls	0	0[1]
Type	Small tears		
Annual cost	Negligible	Negligible[2]	Negligible[1,2]
Propeller damage	?[3]	0	0
Live seals aboard			
Frequency	6.3 (3.3[4]) seals/100 hauls	0[5]	1.25 seals/100 hauls
Annual total	2,672 (1,398[4]) seals/yr	0[5]	1,034 seals/yr
Annual cost attributable to seals	Negligible[3]	>R69,728 (US$18,827)	Negligible[1,2]
Landed value of fishery (1992)	R182,799,000 (US$49,356,000)	R20,930,000 (US$5,651,000)	R6,461,000 (US$1,744,000)
Percentage of landed value lost to seals (1992)	Negligible[3]	>0.3%	Negligible[1,2]
Effect on seals			
Incidental mortality			
Drowning			
Frequency	1.2 (3.8[4]) seals/100 hauls	4.6 seals/100 hauls	94 seals /100 hauls
Annual total	498 (1,610[4]) seals/yr	992 seals/yr	1,034 seals/yr
In propeller	?[3]	0	0
Deliberate mortality			
Potential risk to crew			
Frequency	0.5 (1.0[4]) % of hauls	0[5]	13 seals/100 hauls
Annual total	169 (424[4]) seals/yr	?[5]	143 seals/yr
Annual seal mortality	667 (2,034[4]) + ? [3]	992 + ?[5]	1,177
Percentage mortality from feeding population of 650,000 seals[6]	0.1 (0.3[4]) + ?[3]	0.2 + ?[5]	0.2

[1] By inference from a comparison of the information regarding offshore demersal trawling and differences between demersal and midwater trawling.

[2] No net damage was observed, but the cost is likely to be negligible, if it does occur.

[3] The incidence of seals going through the Kort nozzle, damaging the propeller, and being killed occurs only on some offshore demersal vessels and this may have been resolved. The problem is therefore excluded from the calculation of cost to this fishery.

[4] Figure calculated from Shaughnessy and Payne (1979).

[5] No live seals aboard were observed during the limited number of observations, but live seals are likely to come aboard and may be killed if considered a potential risk to the crew.

[6] There are insufficient data on the age and sex of seals that attend trawling operations or die as a result of their encounter. Pups are unlikely to be on the trawling grounds so the maximum number of seals that may be encountered is the South African proportion (Wickens et al., 1991) of the feeding population (Anonymous, 1991). From all three types of trawling, the total mortality is calculated as 2,836–4,203 seals per year. Overall this amounts to 0.4–0.6% of the feeding population annually.

ate or eliminate the problem are being investigated by the company concerned. Incidental and, on occasion, deliberate mortality of seals, is probably in the order of at most a few thousand seals per year. Of the three seals that drowned during observations, two were female but during inshore trawling the drowned animals were all male. The observations therefore do not show that there is necessarily any bias by sex. It is unlikely that the number of seals dying as a result of offshore trawling operations will have a noticeable negative impact on the total population.

In the inshore trawl fishery, damage to fish is generally considered to be the only problem attributable to seals, and it probably occurs during most hauls to at least some degree. Inshore trawling takes place only on the south coast and seals are generally present during operations in numbers <10. The cost of the damage is believed as small in comparison to the landed value of the fishery. Because the Agulhas sole market requires the fish in gutted (but head-on) form, seal damage can reduce the price per unit mass. With kingklip, there is a loss of landed mass as a result of the trimming of fish to remove seal damage. Incidental seal mortality by drowning is not uncommon during inshore trawling and, though not witnessed, live seals aboard may be killed if the crew is believed to be at risk. The total annual mortality of seals during inshore trawling is probably in the region of a thousand seals per year; again, this is not considered important in terms of the size of the seal population.

During midwater trawling, seals can probably be considered little problem and, if anything, less of a problem than during offshore demersal trawling. Fish in the net are less accessible than on demersal trawls, so seal predation on fish in the net is negligible. Based on the limited number of observations, the number of seals, both alive and drowned, that come aboard in the net can be considered notable per trawl, and live seals aboard that are a potential risk to the crew are deliberately killed. However, given the small number of midwater trawls that take place during a year, the overall number dying as a result of inshore trawling is approximately a thousand per year, considered a negligible loss in terms of the feeding population size.

No particular form of deterrent is considered necessary at this stage to prevent interaction of seals with offshore demersal and midwater trawlers. In order to minimize damage to the catch on inshore trawlers, crews usually try to retrieve the net as quickly as possible. Brightly colored strips of plastic or canvas are sometimes also used to deter the seals, but these have not been very effective. Trials with a device to eliminate the problem with seals and Kort nozzles on offshore trawlers, discussed earlier, are underway.

Facilitation of removal of live seals from trawlers is possibly the only action currently required. Various methods, such as those suggested for the New Zealand trawl fishery, could be tried. These include use of choker poles, deck and fire hoses, and the use of nets (Anonymous, 1990).

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King Mackerel, *Scomberomorus cavalla*, Mark-Recapture Studies Off Florida's East Coast

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Introduction

King mackerel, *Scomberomorus cavalla*, is a coastal, pelagic scombrid found off the U.S. Atlantic and Gulf of Mexico coasts. This species has historically contributed to commercial and recreational catches throughout its range in the southeastern United States. Commercial exploitation intensified there in the 1960's with the introduction of large power-assisted gillnet boats and spotter aircraft. By the late 1970's and early 1980's, increased demand for king mackerel had exceeded reproductive capacity causing stock reductions and declining recruitment (Godcharles[1]). King mackerel have been jointly managed by the South Atlantic and Gulf of Mexico Fishery Management Councils since the implementation of the Coastal Pelagic Fishery Management Plan (CPFMP) in 1983. The maximum sustainable yield (MSY) for the U.S. king mackerel resource is currently estimated at 26.2 million pounds (NMFS[2]).

The recreational fishery for king mackerel grew in importance as the commercial fishery thrived. Moe (1963) stated that in the early 1960's, king mackerel was the species most desired by anglers fishing from private boats, and was the staple catch of Florida's charterboat fleet. In 1990–91, king mackerel was one of the three most highly targeted species by recreational anglers along the southern U.S. Atlantic coast (NMFS, 1992). In recent years, estimated king mackerel recreational catches have exceeded reported commercial landings in both the Atlantic and Gulf of Mexico (Fig. 1).

In 1975, the Florida Department of Natural Resources (FDNR), now the Florida Department of Environmental Protection (FDEP), and the National Marine Fisheries Service (NMFS) Panama City Laboratory, began a cooperative mark-recapture study on king mackerel to determine movements in both the Gulf of Mexico and along the Atlantic coast. Subsequently, biologists from both agencies tagged king mackerel (17,042 releases, 1,171 returns) from 1975 through 1979 (Sutherland and Fable, 1980; Sutter et al., 1991; Williams and Godcharles[3]). Results from this study indicated that the species consisted of at least two migratory groups (stocks). Ranges of the two stocks basically coincided with the Gulf of Mexico and the Atlantic Ocean off the southeast U.S. coast, with some mixing of the stocks off southeastern Florida during winter months.

These conclusions were the primary basis for the division of the Gulf of Mexico (Gulf) and Atlantic king mackerel stocks, as defined by Amendment 1 to the CPFMP (Gulf of Mexico and South Atlantic Fishery Management Councils, 1985). Variable stock boundaries are used as part of the management strategy. The Gulf group is separated from the Atlantic group 1 April–31 October at the Collier/Monroe County line in southwest Florida and 1 November–31 March at the Flagler/Volusia County line in northeast Florida (Fig. 2). The area between the Collier/Monroe County line and the Flagler/Volusia County line in Florida is considered to be a mixing area for the Gulf and Atlantic migratory groups and is referred to within this text as the "mix-

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ABSTRACT—King mackerel, Scomberomorus cavalla, *were tagged and released from eastern Florida between 1985 and 1993. Recapture trends from these studies indicate an increase in tag returns from areas north of the release sites, along with a decrease in recaptures from coastal waters in the Florida Keys and Gulf of Mexico, since earlier king mackerel tagging studies completed in the late 1970's. The data indicate that eastern Florida waters may maintain resident king mackerel. Cyclical tag return patterns were noted along eastern Florida and in North Carolina. The proportion of mixing of presently defined king mackerel stocks along eastern Florida may vary yearly. Comparison of king mackerel tags show internal anchor tags to have a higher percentage of return and lower percentage of tag loss than dorsal dart tags.*

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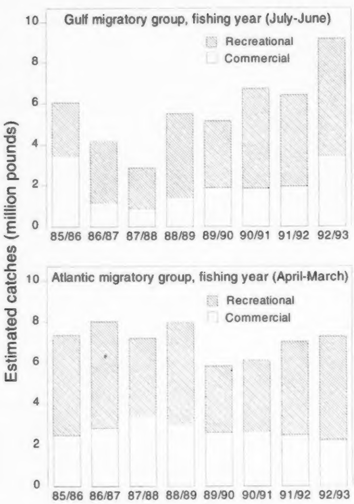

Figure 1.—Estimated catches of king mackerel from the Gulf and Atlantic stocks by fishing year (FY). Source: NMFS (1994).

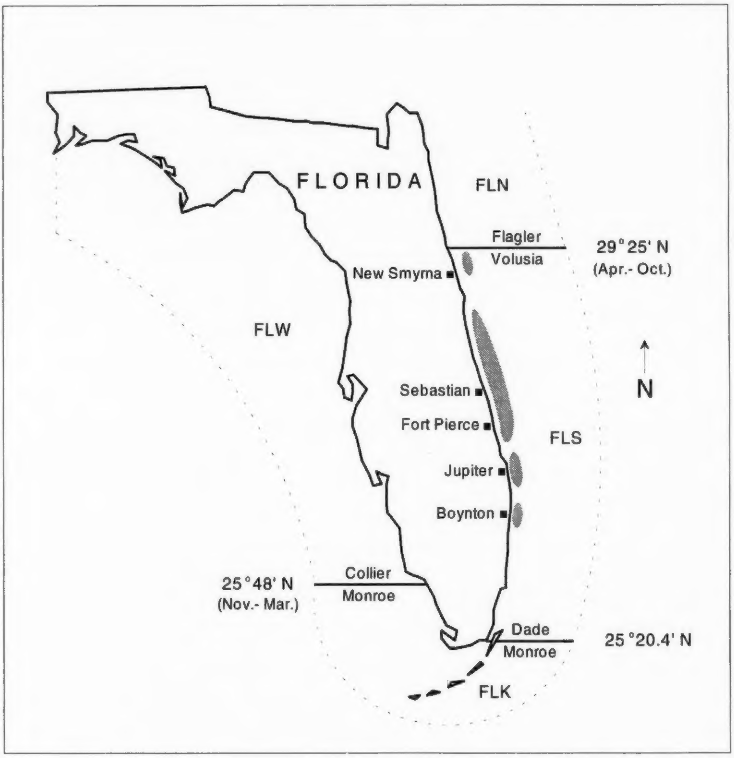

Figure 2.—NMFS tagging locations (shaded), variable Atlantic/Gulf stock boundaries, and subareas used to partition Florida tag returns.

ing zone." For management purposes, the commercial sector of the Gulf group is partitioned into the eastern (Florida) and western (Alabama to Texas) zones. Annual quota allocations and bag limits are enforced for each migratory group in accordance with the fishing year (FY). The Gulf group FY is defined as 1 July–30 June and the Atlantic group FY as 1 April-31 March.

In 1983, the NMFS began additional scientific mark-recapture work to further evaluate movement patterns of king mackerel within Gulf of Mexico and Atlantic waters. Since then, tagging studies have been conducted off Mexico, Texas, Louisiana, northwest and eastern Florida, and North Carolina. The primary objective of tagging along Florida's east coast was to better understand mixing patterns of king mackerel from the eastern Gulf group and the Atlantic group. This paper summarizes the current results of the NMFS mark-recapture work from 1985 through 1993 along eastern Florida.

Methods

For continuity, earlier king mackerel tagging studies (1975–79) by the state of Florida and NMFS are referred to as FDEP tagging. The tagging methods and techniques for procurement of fish follow the original procedures developed during the FDEP study. Although only internal anchor (IA) tags were used for the earlier FDEP tagging (Sutter et al., 1991), the NMFS has experimented with four different types of king mackerel tags from 1985 through 1993 (Fig. 3). Single red or orange plastic IA tags, similar to those used during the FDEP study, were used during 1985–88. Orange shrink-lock internal anchor (SLA) tags were tested along with IA tags during winter 1989–90 tagging. Yellow double-barb dorsal dart tags (DD92) were used in combination with IA and SLA tags during 1991–92 tagging. The following winter (1992–93), a new version of the dorsal dart tag (DD93) was tested along with IA tags. All tags included an identification number and return address or phone number printed on the streamer. IA and SLA tags also included the tag number printed on the disk portion.

During all of the tagging studies described, commercial handline fishermen were contracted to catch king mackerel for tagging. These fishermen were compensated for successfully tagged and released fish based on the total weight of marked releases during each trip, as calculated using a weight to length conversion table. Although this method of procurement proved costly, large numbers of relatively unharmed fish were usually available for tagging, and accurate information on releases could be obtained by NMFS personnel (Fable, 1990).

King mackerel were caught using commercial troll gear. Fish were immediately unhooked aboard the vessel and

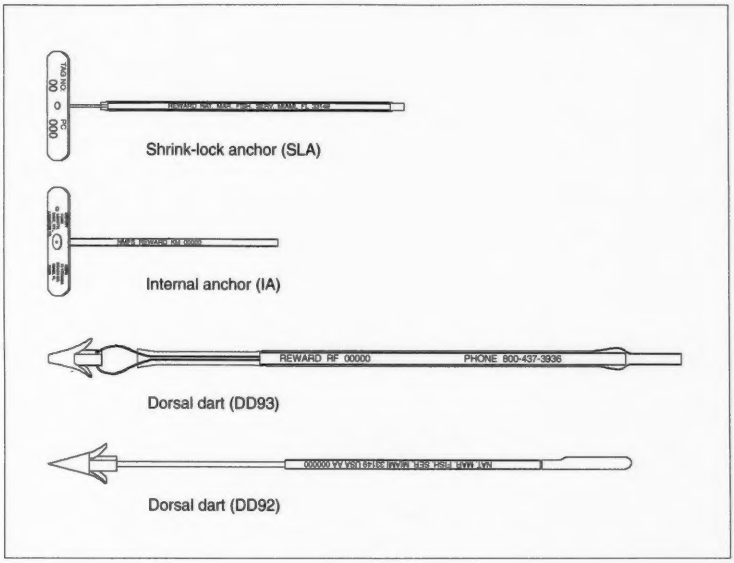

Figure 3.—Types of king mackerel tags used by NMFS during 1985–93.

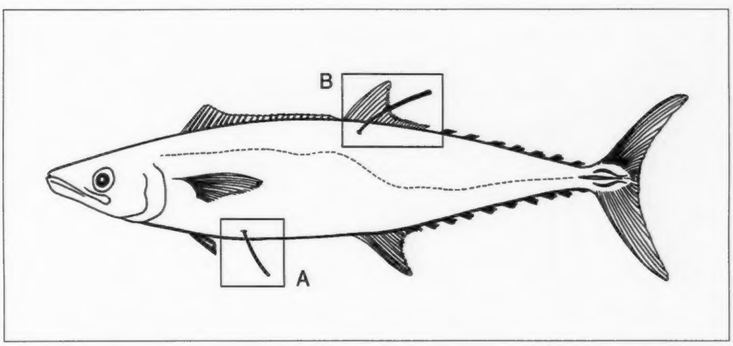

Figure 4.—Placement of internal anchor (IA and SLA) tags (A) and dorsal dart (DD92 and DD93) tags (B).

placed ventral side up in a V-shaped trough. Prior to 1991, IA tags were inserted with forceps into the abdominal cavity through a 6–10 mm slit made with a scalpel. During 1991–92 and 1992–93 tagging, IA and SLA tags were inserted using a stainless steel insertion tool designed by the NMFS Panama City Laboratory. With both methods, the disk portion of the tag remained inside the abdominal cavity, and the plastic streamer protruded externally (Fig. 4). Double-barbed dart tags were inserted beside the dorsal fin into the musculature using a short-handled insertion needle. Immediately after tagging and measurement, presumed healthy fish were released over the side of the boat. Information recorded for each released fish included tag numbers, fork length, month-day-year, latitude-longitude, and condition of fish. Release information was ultimately entered into a release and recapture database, currently managed by the NMFS Cooperative Gamefish Tagging Program, Miami.

Initially, to publicize the king mackerel tagging program and to reward anglers for returning tags, posters and news releases were circulated, and a $10 reward was offered for each returned tag. In 1986, to help increase the tag returns, an annual $1,000 drawing, sponsored by NMFS, was added to the reward program. In 1991, the individual reward was increased to $20 per fish.

Release and recapture data for the described studies (10,285 releases, 546 returns) were compiled from the NMFS Panama City Laboratory tagging records and the NMFS Cooperative Gamefish Tagging Program database. Six separate tagging experiments, conducted by the NMFS from 1985 through 1993, are described here. Table 1 lists the locations, dates, and release numbers during each experiment. No tagging was performed during winter 1990–91. The number of fish released during these studies (10,285) is comparable to the number released in eastern Florida during the 1970's FDEP study (10,120).

To describe movement patterns, releases were grouped into three spatial/temporal regions. Recaptures were grouped into the geographical location of recovery, taking into account the present management strategy. Returns from outside of Florida were partitioned into the state of recapture. Due to its expansive coast line and the high proportion of returns, Florida was divided into four subareas: Collier/Monroe County line to Alabama (FLW), Collier/Monroe County line to Dade/Monroe County line (FLK), Dade/Monroe County line to Flagler/Volusia County line (FLS), and Flagler/Volusia County line to Florida/Georgia border (FLN) (Fig. 2).

Recaptures were also grouped according to the ocean of recovery, using the Gulf of Mexico and Atlantic Ocean, as defined by the Supreme Court decision, United States v. Florida, October term 1975. No adjustments were made for possible factors affecting tag return rates. Temporal relationships were described by grouping recaptures by season and area of recapture in relation to time of freedom. Seasons are divided as 3-month periods: winter is defined

as December, January, and February; spring as March, April, and May; summer as June, July, and August; and fall as September, October, and November. One recapture from the 1987 tagging study, returned from a New York fish market, was not included for movement analysis.

Results

The mean fork length (FL) varied for each study with the largest fish tagged during the 1985–86 and 1987 studies (Table 1). Fish tagged during winter in southeast Florida (1988–93) averaged largest at the beginning of the winter for each study. Length frequency histograms, comparing percentages of releases to recaptures (5 cm grouping) show that a larger percentage of fish were released than were recaptured in smaller size groupings (<65 cm FL) (Fig. 5). This is most evident in the histogram developed from 1991–92 tagging.

Table 1.—Summary of size distribution of king mackerel releases.

Tagging Study						
Years	Months	Location	No. tagged	Mean FL (mm)	S.E.	Size range FL (mm)
1985–86	Dec., Jan.	New Smyrna	891	872	10.9	540–1,180
1987	April, May	Jupiter	719	891	10.2	670–1,270
	April, May	Boynton	284	871	8.7	600–1,200
		Combined	1,003	885	9.7	600–1,270
1988–89	Dec.	Sebastian	599	879	7.9	525–1,450
	Jan.–March	Ft. Pierce	1,228	731	7.5	460–1,175
	March, April	Boynton	216	729	7.4	510–980
		Combined	2,043	774	6.1	460–1,450
1989–90	Dec.	Sebastian	288	744	6.6	540–1,160
	Jan.–March	Ft. Pierce	1,763	697	5.9	435–1,200
	April	Boynton	3	630	12.9	570–690
		Combined	2,054	703	6.0	435–1,200
1991–92	Dec., Jan., March	Sebastian	740	763	7.3	420–1,190
	Feb.	Ft. Pierce	638	672	8.0	480–1,120
	March	Jupiter	838	613	7.9	410–1,130
		Combined	2,216	680	6.2	410–1,190
1992–93	Dec., Jan.	Sebastian	296	854	6.9	560–1,370
	Feb., March	Jupiter	1,729	763	7.5	480–1,220
	March	Ft. Pierce	53	716	12.3	590–880
		Combined	2,078	775	7.1	480–1,370

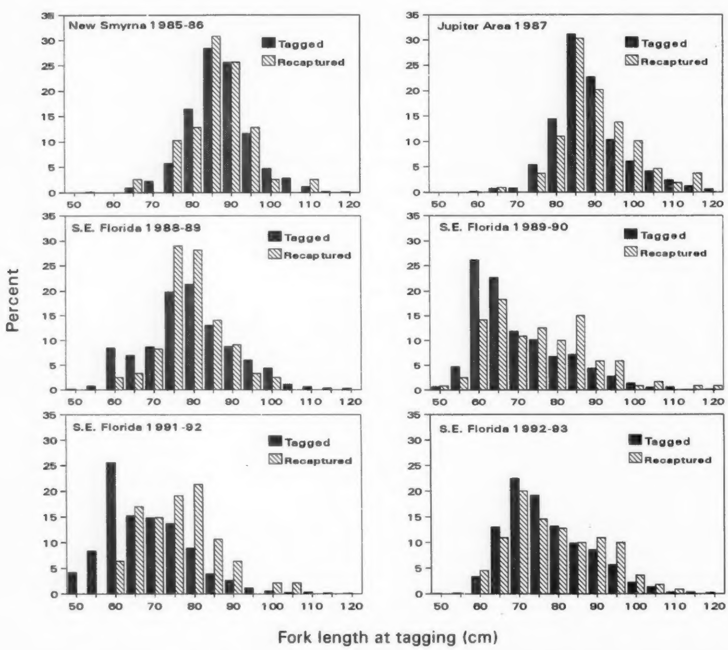

Figure 5.—Length frequency distribution of releases and returns from 1985-93 king mackerel tagging (5 cm groupings).

The largest percentage of returns occurred within the first year following release for all studies with decreasing returns during each year thereafter (Table 2). The overall return rate from these studies is thus far 5.3%. Time at large varied from 0 to 2,261 days, averaging 360 days. Returns from the western zone of the Gulf of Mexico indicated the farthest distance traveled away from the point of release. All of the fish recaptured in Texas (3) were estimated to have traveled over 2,000 km. The most distant Atlantic recapture (1,430 km) was recovered from Virginia Beach, Va. Interestingly, 37.9% (207) of all recaptures were recovered within 50 km of tagging with 37.2% (77) of these at large for more than 1 year. Of the 248 fish recaptured more than 100 km away from the point of tagging, 63.3% were recovered from north of the tagging location. There was no observed relation between size and distance traveled. Due to spatial/temporal variations in tagging regions, recapture results of these studies are treated separately. Results from winter 1988–93 tagging in southeast Florida are treated both separately and combined, since tagging occurred within the same spatial/temporal area.

Table 2.—Number of recaptures per 12-month period following release.

	Days from release to recapture							
Tagging period	0–365	366–730	731–1,095	1,096–1,460	1,461–1,825	1,826–2,190	2,191–2,555	Percent return
1985–86	18	12	6		3			4.0
1987	53	34	10	5	6	1		10.9
1988–89	87	20	7	5	1		1	5.9
1989–90	60	43	13	3	1			5.8
1991–92	35	8	4					2.1
1992–93	82	27	1					5.3
Totals	335	144	41	13	11	1	1	5.3

Winter Tagging 1985–86, New Smyrna Beach Area

Most of the recaptures (38) from fish tagged during winter in the New Smyrna Beach area (891 releases, 39 returns) were found along eastern Florida (Fig. 6, Table 3). One fish was recovered from the Gulf of Mexico off Louisiana in October 1987. All recoveries from north of the tagging area occurred summer through fall, while the majority of recoveries from south of the tagging area were concentrated during winter and spring months in southeast Florida. Results indicate that this group of fish may have been primarily residential (nonmigratory) off eastern Florida. The lack of tagging within this region during the FDEP study does not allow comparison of these results to those of 1970's tagging.

Spring Tagging 1987, Jupiter Area

Recaptures from April and May tagging in the Jupiter area (1,003 releases, 109 returns) ranged along the Atlantic coast from Virginia to the Florida Keys (Fig. 7). Outside of Florida, the majority of the recoveries (19) were from North Carolina in the fall. Only one tag was returned from the Gulf of Mexico—in the fall off Panama City, Fla. Temporal return patterns show the highest number of recaptures in southeast Florida during spring for four consecutive years following the tagging, as well as recurrent returns in North Carolina in the fall for more than four years following tagging (Table 4). Thirty percent of returns (33) from this study were fish at large for more than 1 year and recaptured within a 50 km radius of release. A comparison of these results to those of the FDEP study show a marked decrease in the number of Gulf of Mexico and Florida Keys returns along with an increase in southeast U.S. Atlantic coast returns (Table 6).

Winter Tagging 1988–93, Southeast Florida

From 1988–93 the NMFS tagged 8,391 king mackerel in the same region in southeast Florida during four winters (Table 1). Recaptures from 1988–89 tagging (2,043 releases, 121 returns) show extensive movements (Fig. 8). Atlantic Ocean returns ranged from North Carolina to the Florida Keys. Gulf of Mexico returns (7) ranged from western Florida to Texas, and occurred in late spring to early fall. Recaptures from north of the Flagler/Volusia border (15) occurred in the spring and summer months. Recaptures within southeastern Florida occurred during all months of the year, but were concentrated during the winter in the Cape Canaveral to Fort Pierce area and during May in the Jupiter to Palm Beach area. Fish tagged during mid-winter off Fort Pierce showed the most movement, accounting for five of the seven Gulf returns and all of the five Atlantic returns north of Florida.

Recaptures from 1989–90 tagging (Fig. 9) show fewer Gulf of Mexico returns (5) than from the previous study coupled with more returns from areas north of the Volusia/Flagler border (29) (Table 3). Fish tagged in mid-winter off Fort Pierce again showed the strongest tendency to move, providing all of the Gulf of Mexico returns and 11 returns from north of Florida. Returns from north of the tagging area were concentrated from spring through fall. Southeast Florida returns occurred year-round with the highest number during winter off the Cape Canaveral to Fort Pierce area.

Movement, as indicated by the distribution of tag returns from 1991–92

Table 3.—Distribution of king mackerel tag returns.

	Tagging period						
Recapture location	1985-1986	1987	1988-1989	1989-1990	1991-1992	1992-1993	All years
Virginia		1			1		2
N. Carolina		19	2	7	3	2	33
S. Carolina		2	2	6	1	2	13
Georgia		2	1	2		3	8
Florida[1]							
FLN[1]	11	5	10	14	3	13	56
FLS	27	74	94	84	38	88	405
FLK		4	5	2		2	13
FLW		1	4	4			9
Alabama					1		1
Louisiana	1		1				2
Texas			2	1			3
Unknown		1					1
Totals	39	109	121	120	47	110	546

[1] See Figure 1 and text for description of Florida subareas.

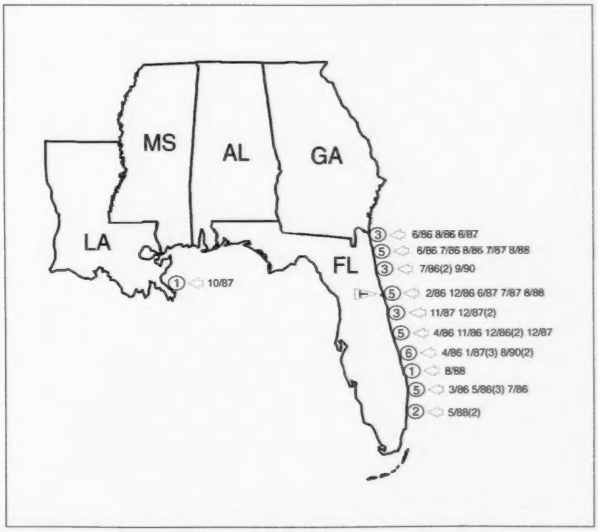

Figure 6.—Location and month/year of tag returns from 1985–86 tagging in the New Smyrna Beach, Fla., area.

tagging (2,216 releases, 47 returns), was restricted primarily to the Atlantic coast (Fig. 10, Table 3). Tag recoveries ranged along the Atlantic coast from Virginia to Miami, Fla. No tags were returned from the Florida Keys, but one tag was returned from the Gulf of Mexico off of Fort Morgan, Alabama. Recapture trends show northward movement in the spring and summer of 1992 and recurring recaptures in southeast Florida the following two winters.

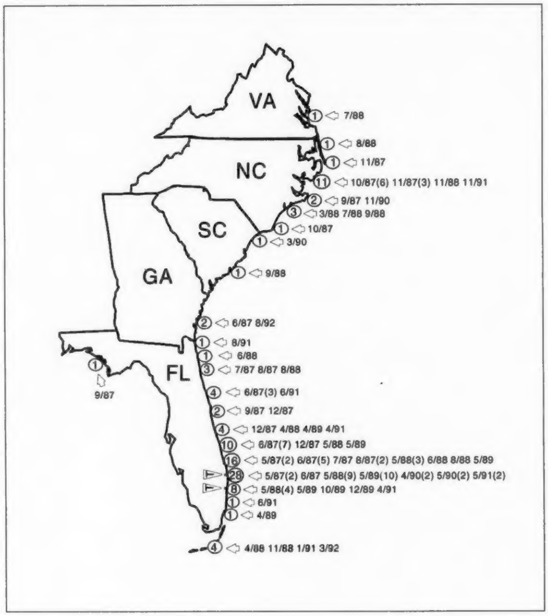

Figure 7.—Location and month/year of tag returns from 1987 tagging in the Jupiter, Fla., area.

Table 4.—Number of returns from Jupiter 1987 tagging by recapture location, days at large, and season of recapture.

Release to return (days)	Season of recovery[2]	Recapture location[1] Florida FLW	FLK	FLS	FLN	GA	SC	NC	VA
0–365	Winter			3					
	Spring		1	12				1	
	Summer			19	2	1			
	Fall	1		1				12	
366–730	Winter								
	Spring			22					
	Summer			2	2			2	1
	Fall		1				1	2	
731–1,095	Winter			1					
	Spring			7			1		
	Summer								
	Fall			1					
1,096–1,460	Winter		1						
	Spring			3					
	Summer								
	Fall							1	
>1,460	Winter								
	Spring		1	1					
	Summer			2	1	1			
	Fall							1	

[1] States outside of Florida are abbreviated; see Figure 1 and text for description of Florida subareas.
[2] Seasons are divided as 3-month periods (i.e. winter is Dec., Jan., Feb.).

Table 5.—Number of returns from 1988-93 tagging in southeast Florida by recapture location days at large and season of recapture.

Release to return (days)	Season of recovery[2]	Recapture location[1] TX	LA	AL	Florida FLW	FLK	FLS	FLN	GA	SC	NC	VA
0–365	Winter					1	51					
	Spring				2	3	121	4	1	1		
	Summer	1			3	1	20	21	3	3	4	1
	Fall		1				19	1		1	1	
366–730	Winter					2	15			1	1	
	Spring				1		25	3		3	1	
	Summer				2	1	17	9			2	
	Fall	1					8		1	2	3	
731–1,095	Winter						6					
	Spring					1	9					
	Summer	1		1			1	1			1	
	Fall						4					
1,096–1,460	Winter						1					
	Spring						4					
	Summer							1	1		1	
	Fall											
>1,460	Winter						2					
	Spring											
	Summer						1					
	Fall											

[1] States outside of Florida are abbreviated; see Figure 1 and text for description of Florida subarea.
[2] Seasons are divided as 3-month periods (i.e., winter is Dec., Jan., Feb.).

Recaptures from 1992–93 tagging (2,078 releases, 110 returns) are thus far confined to the Atlantic coast (Fig. 11). Seven fish were recovered north of Florida during spring through fall. Fish tagged later in the winter in Jupiter accounted for five of these seven returns and for the two returns from the Florida Keys. No fish have yet been recaptured in the Gulf of Mexico.

Combined results from winter tagging 1988–93 (8,391 tagged, 398 returns) show distinct differences from earlier FDEP tagging (Table 6). Williams and Godcharles[3] reported that migrating king mackerel tagged in the winter off southeast Florida moved principally into the Gulf of Mexico during the summer. More recent NMFS tagging indicates that only 3.3% (13) of all recaptures occurred north of the Collier/Monroe County line in the Gulf of Mexico, while 18.1% (72) were from north of the Volusia/Flagler County line in the Atlantic. Returns from within the Florida mixing zone (313) occurred nearly exclusively within the Atlantic Ocean. One fish was recaptured from Gulf of Mexico waters near Summerland Key. Thus, only 3.5% (14) of returns actually occurred within the Gulf of Mexico. There has been only one return as of yet from the Gulf of Mexico from the 1991–1993 tagging (4,294 releases, 157 returns) in southeast Florida.

Recaptures from southeast Florida occurred during all months of the year (Table 7). The number of recaptures occurring there from November through March (140) was actually smaller than those occurring from April through October (164). Seasonal grouping of returns from 1988–93 tagging show that although most tag recoveries during the winter and spring were in southeast Florida, by summer 49.5% of recoveries were from areas north of the Flagler/Volusia County line. Summer returns

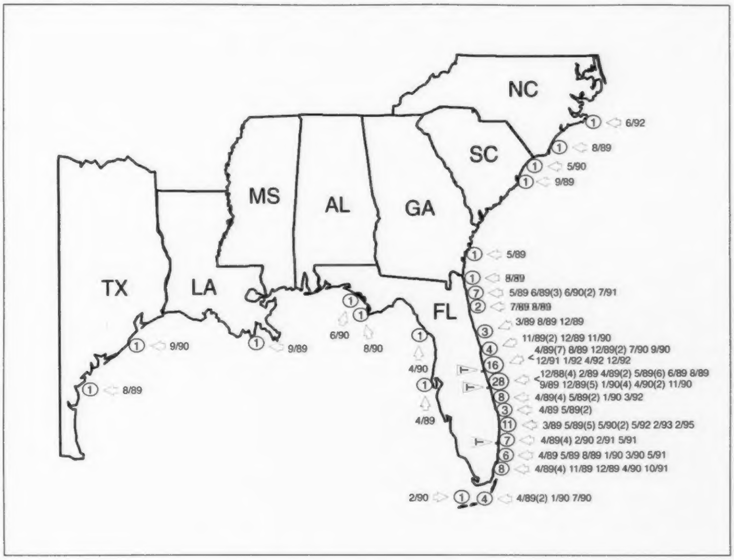

Figure 8.—Location and month/year of tag returns from 1988-89 southeast Florida tagging.

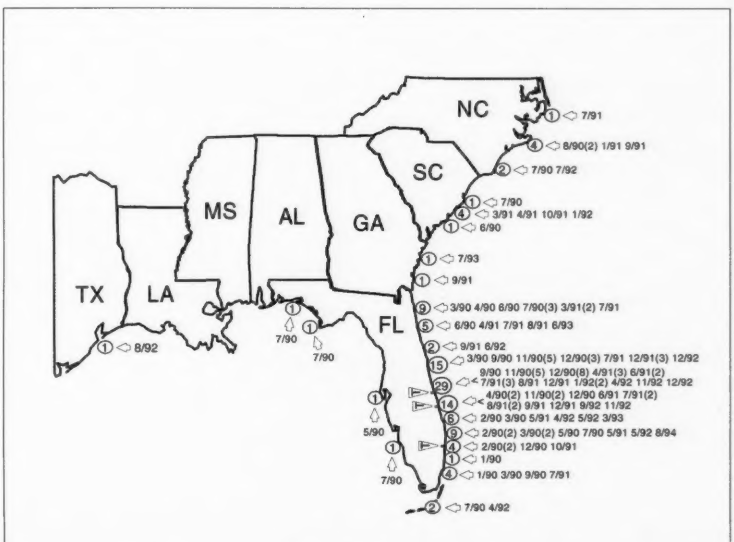

Figure 9.—Location and month/year of tag returns from 1989-90 southeast Florida tagging.

Table 6.—Comparison of NMFS tagging to earlier FDEP tagging showing the number of releases in parentheses.

	Jupiter area (May–June tagging)		S.E. Florida area (Dec.–April tagging)	
Recapture location	FDEP 1975–78 (2,674[1])	NMFS 1987 (1,003[1])	FDEP 1975–78 (6,500[1])	NMFS 1988–93 (8,391[1])
Virginia	2	1		1
N. Carolina	6	19	4	14
S. Carolina	5	2	1	11
Georgia	1	2	1	6
Florida[2]				
FLN	8	5	6	40
FLS	146	74	436	304
FLK	30	4	45	9
FLW	2	1	36	8
Alabama			4	1
Louisiana	1		3	1
Texas	5		16	3
Unknown	1	1	1	
Totals	207	109	553	398

[1] Number of releases.
[2] See Figure 1 and text for description of Florida subareas.

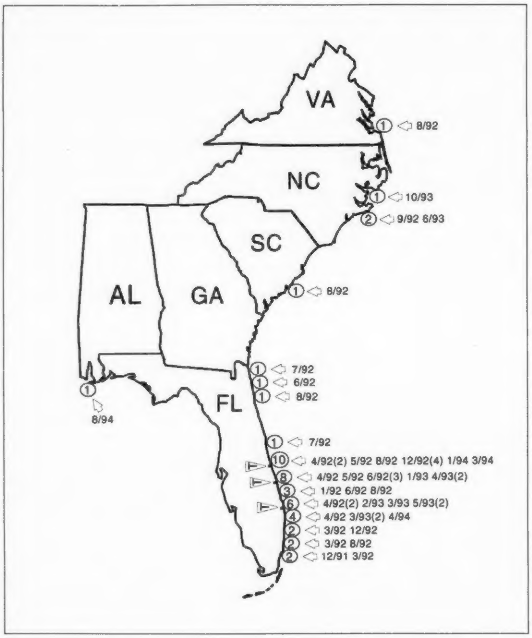

Figure 10.—Location and month/year of tag returns from 1991–92 southeast Florida tagging.

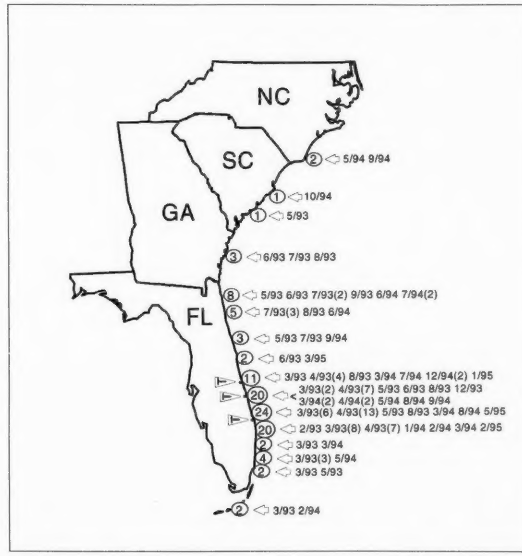

Figure 11.—Location and month/year of tag returns from 1992-93 southeast Florida tagging.

also included the highest number from the Gulf of Mexico (8) and from the Atlantic north of Florida (16). Fall returns, the lowest of any season, were concentrated along the Atlantic coast with the highest number of returns in southeast Florida. Temporal patterns show repeated returns in North Carolina in the summer and fall (Table 5). Recaptures from northeast Florida also showed a pattern of repeated returns in spring and summer.

Tag Comparisons

During the first three tagging studies (1985–86, 1987, 1988–89), all fish were single-tagged using IA tags (4.0–10.9% return). Results of 1989–90 tagging show that there were no appreciable differences in return rates (5.6–6.1%) from all of the four tag combinations of SLA and IA tags tested (Table 8). Tag loss was lower for SLA tags (16.0-22.5%) than IA tags (30.0%). During winter 1991-92 tagging, IA, SLA, and DD92 tags showed varying return rates per combination (0.5-5.3%). DD92 tags had a higher calculated tag loss (50.0-57.1%) than SLA (0%) or IA tags (10.7%). Tagging in 1992-93, which involved testing a new type of dorsal dart tag (DD93) along with IA tags also, showed varying rates of return per combination (0-7.1%). DD93 tags showed a much higher tag loss (54.4%) than IA tags (12.3%).

Early recaptures from 1992-93 tagging provided a clue to problems associated with the DD93 tag. Several double–tagged fish were recaptured with both tags intact, but with a large open wound slanting posteriorly from the DD93 tag (Fig. 12). We believe that vibrations of the streamer against the soft dorsal skin and tissue were progressively creating a larger hole surrounding the tag. Constant motion of the fish

Table 7.—Number of returns from 1988-93 tagging in southeast Florida by recapture location and season and month of recovery.

Recapture location	Winter			Spring			Summer			Fall		
	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Virginia									1			
N. Carolina		1				1	2	3	3	3	1	
S. Carolina		1		1	1	2	1	1	1	1	2	
Georgia						1	1	2	1	1		
Florida												
FLN[1]				3	2	2	12	15	5	1		
FLS	45	16	14	46	76	37	11	12	16	10	2	19
FLK		1	2	1	3			2				
FLW					2	1	1	3	1			
Louisiana										1		
Alabama									1			
Texas									2	1		
Totals	45	19	16	51	84	44	28	38	31	18	5	19

[1] See Figure 1 and text for description of Florida subareas.

and streamer of the DD93 tag would probably not allow such a wound to heal before the tag fell out. Supporting this theory, several other double-tagged fish were recaptured with the DD93 tag missing and a gaping wound where it had been inserted.

These experiments indicate a higher tag loss from both DD92 and DD93 tags than either SLA or IA tags. Double-tagged fish with one dorsal dart tag and one internal anchor tag also showed a lower percentage of return than those fish single- or double-tagged using only internal anchor tags, especially for smaller fish (<700 mm FL).

Discussion

The actual mechanisms of king mackerel migration are not well known. The highly pelagic nature of this species is evidenced by the range of recaptures from these studies (from Texas to Virginia). Recaptures from the Gulf of Mexico suggest that there has been at least limited migration from southeast Florida, beyond the Collier/Monroe County line, to both the eastern (9 returns) and western (6 returns) zones of the Gulf of Mexico. The percentage of cross mixing of king mackerel populations (i.e. fish that are spawned in the Atlantic Ocean and later travel to the Gulf of Mexico) has yet to be documented.

Important factors such as differential fishing mortality rates, variable tag reporting rates, fishery closures, and changes in fishing patterns have not been weighted for in this study. Differences in reporting rates of tagged fish most likely occur between different localities and among different resource users. The familiarity of fishermen in southeast Florida with the NMFS tagging program has undoubtedly contributed to the high return rate recorded there. Florida's east coast also supports intensive year-round king mackerel fishing, unlike certain areas in the Gulf of Mexico and north of Florida. The implementation of the CPFMP in 1983 did not affect the recoveries from earlier FDEP tagging, but has undoubtedly affected tag recoveries since the onset of recent NMFS tagging.

From 1987 through 1993 the commercial and recreational fisheries for Gulf migratory group king mackerel were closed for varying periods in the winter and spring, thereby eliminating tag recoveries which would have occurred both within south Florida and the Gulf of Mexico. Due to the complexity of interactions affecting tag returns and the relatively large area encompassed by these studies, no adjustments were attempted for these differences or their

Table 8.—Summary information on king mackerel releases by tag type showing percentage of tag loss in parentheses.

		Release		Return		
Tagging period	Tag combinations	No.	Mean FL(mm)	N	%	Tags not recovered
1985–86	1 IA	891	872	39	4.0	
1987	1 IA	1,003	885	109	10.9	
1988–89	1 IA	2,043	774	121	5.9	
1989–90	1 IA	33	636	2	6.1	
	1 SLA	510	697	31	6.1	
	1 IA + 1 SLA	675	698	40	5.9	12 IA(30.0%) 9 SLA(22.5%)
	2 SLA	836	714	47	5.6	15 SLA(16.0%)
1991–92	1 IA	287	673	2	0.1	
	1 SLA	188	690	10	5.3	
	1 DD92	197	616	1	0.5	
	1 SLA + 1 DD92	387	661	6	1.6	3 DD92(50.0%)
	1 IA + 1 DD92	1,157	698	28	2.4	3 IA(10.7%) 16 DD92(57.1%)
1992–93	1 IA	749	745	53	7.1	
	1 DD93	28	740			
	1 IA + 1 DD93	1,301	793	57	4.4	7 IA(12.3%) 31 DD93(54.4%)

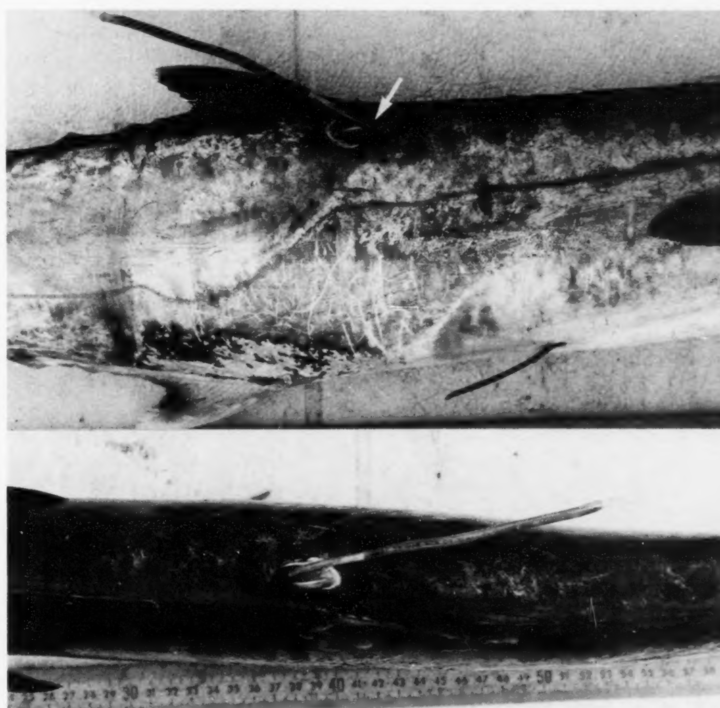

Figure 12.—King mackerel recaptured 60 days following tagging, showing a large wound surrounding the dorsal DD93 tag.

effects on results of this research. All results and conclusions within this text are based solely on the most current NMFS return data.

Sutter et al. (1991) estimated that seasonal overlap between the Gulf and Atlantic stocks off southeastern Florida in the late 1970's was 29.4-41.8%. These estimates were based upon the present management strategy, which classifies all king mackerel off southeast Florida in the winter (1 November–31 March) as eastern Gulf migratory group. Preliminary results of these NMFS studies continue to support the theory of separate Gulf of Mexico and Atlantic king mackerel stocks, but may indicate less mixing of these two groups along Florida's east coast than previously theorized.

Returns from the NMFS tagging studies along eastern Florida, which are likely to increase in the future (Table 2), suggest that only a small percentage of king mackerel tagged in the southern Atlantic from winter through early summer migrated into the Gulf of Mexico. This decrease in Gulf of Mexico recaptures, coupled with an increase in recaptures from north of southeast Florida, could be indicative of an alteration of migration patterns since completion of the FDEP tagging 15 years ago. It may be that as the Gulf group decreased in biomass in the early 1980's the number of fish migrating from the Gulf of Mexico to southeast Florida in the winter also decreased. This may have decreased the size of the winter population off southeast Florida, thereby causing the Atlantic stock to occupy a greater percentage of that population. Differential fishing mortality rates and changes in fishing patterns since the FDEP study may be other explanations for differences between the two studies. Environmental and biological parameters, such as water temperatures, storms, and the abundance of food may also influence annual migration patterns.

A brief overview of the entire NMFS Cooperative Gamefish Tagging Program king mackerel release and recapture database 1985-1993 (20,393 releases, 994 returns) indicates that only two fish from outside of these studies were released in the Atlantic and recaptured in the Gulf of Mexico, along with seventeen fish that were tagged in the Gulf of Mexico and recaptured in the Atlantic. This low transfer of tagged fish between these two areas, as indicated by recaptures, concurs with the results of these studies. Releases and recaptures within the Florida Keys region were sorted by latitude and longitude to establish Gulf of Mexico or Atlantic Ocean status.

When recaptures are grouped according to current stock boundaries (Fig. 13), the percentage of returns classified as Gulf group is inflated by the large number of winter returns from southeast Florida. If this area is actually no longer a major mixing area for stocks from the Gulf of Mexico and the Atlantic Ocean, as suggested by recent tagging, the majority of these returns may actually be Atlantic group fish. We thus decline to offer a percentage of stock mixing off southeastern Florida based on current variable stock boundaries.

Tagging results also indicate the possibility of a nonmigratory (resident) eastern Florida group, which moves seasonally along the Florida east coast. Winter tagging studies showed year-round recaptures within southeast Florida with a larger percentage occurring during summer months. Sutter et al. (1991) also noted indications of a resident population in southeast Florida during earlier FDEP tagging. Temporal patterns from 1987 and 1988–93 tagging show that the highest number of returns within southeast Florida occurred during the same season as tagging regardless of time at large, implying that there is a regrouping of some of the same fish each winter and spring in southeast Florida (Tables 4, 5).

In conclusion, long-distance migration of winter fish away from southeast Florida seems to start in early spring with a small percentage of fish moving into the Gulf of Mexico by summer and a larger percentage moving northward in the Atlantic, as far as Virginia, by summer and fall. Spring and early summer tagging in the Jupiter, Fla., area showed that long-distance migrating fish moved predominately northward

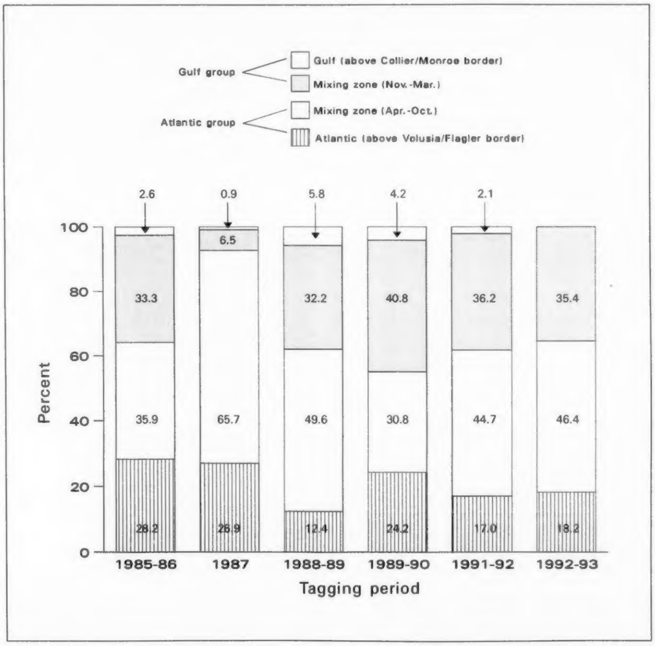

Figure 13.—Percentage of recaptures within present management zones.

during the first few months following tagging, reaching North Carolina by fall (Table 4). The large number of returns from North Carolina from both winter and spring tagging in southeastern Florida suggests that there may be substantial migration between these two areas.

Movement of king mackerel from North Carolina to southeast Florida has been documented by the North Carolina Division of Marine Fisheries. Noble et al.[4] reported that the state of North Carolina tagged and released king mackerel off the central and northern coast of North Carolina (4,364 releases, 86 returns) from 1985 through 1990. The majority of recaptures from south of North Carolina occurred in southeast Florida (15), all in an area from Fort Pierce to Pompano Beach. Seven of these Florida returns were from fish tagged in the early winter in North Carolina and recaptured in the Jupiter area in April and May.

Southeast Florida remains an active fishing area for king mackerel. Results of these studies indicate that the proportion of mixing of presently defined stocks during winter in this area may vary yearly. Mark-recapture work has helped to define migration patterns, but there are many variables affecting tag returns.

Recent electrophoretic variation research has identified limited genetic variation of king mackerel in U.S. waters. Fish samples taken from the western zone of the Gulf of Mexico showed genetic variation from fish samples taken in the Atlantic, but fish captured off western Florida in the Gulf of Mexico are thus far genetically indistinguishable from those found in the southeastern Atlantic (Johnson et al., 1994; NMFS[2]). Research to better define king mackerel populations is underway, and it includes mitochondria DNA analysis by Texas A&M University and a multivariate statistical procedure based upon otolith shape being tested by NMFS. The NMFS has continued mark-recapture of king mackerel in southeast Florida during the winters of 1993-94 (495 releases) and 1994-95 (952 releases). Results of this recent tagging are still preliminary, but do not yet include any recaptures from the Gulf of Mexico.

Acknowledgments

We thank those directly related to the success of these studies, including contracted commercial fishermen and the many NMFS personnel who helped with fish tagging. We also thank all of those at the NMFS Southeast Fisheries Science Center in Miami who helped with this project, including N. Thompson, G. Davenport, and N. Parrack for editorial assistance, along with A. Martinez and J. Javech for help with several figures used, and the NMFS Cooperative Gamefish Tagging Program. Partial funding for this research was provided by grants from MARFIN.

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Observations of the 1992 U.S. Pelagic Pair Trawl Fishery in the Northwest Atlantic

PATRICIA GERRIOR, AMY S. WILLIAMS, and DARRYL J. CHRISTENSEN

Introduction

Pelagic pair trawling involves a large-mesh, mid-water net towed between two vessels usually of similar size and horsepower. Meshes are several meters large at the mouth of the net decreasing in size back to the codend where they range from 13 to 30 cm. Large-mesh pelagic pair trawls have been used in the Northeast Atlantic primarily for albacore, *Thunnus alalunga*, (Prado, 1988; Anonymous, 1991) and off Mozambique, Africa, for several species of tunas (Schwarz[1]).

[1] A. Schwarz. 1993. Rio Rivuma, Boston, Mass. Personal commun.

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ABSTRACT—Pelagic pair trawling for tuna, Thunnus *spp., and swordfish,* Xiphias gladius, *was introduced in U.S. Northwest Atlantic waters in 1991. During autumn (October–November) of 1992 under the authority of the Federal Atlantic Swordfish Regulations, the National Marine Fisheries Service placed observers aboard pelagic pair trawl vessels to document the catch, bycatch, discard, and gear used in this new fishery. The fishery is conducted primarily at night along shelf-edge waters from June to November. In late 1991, revised regulations restricted swordfish to bycatch in this fishery resulting in pelagic pair trawl vessels targeting tuna throughout 1992. Analyses of 1992 data indicate that albacore,* T. alalunga, *was the predominant species caught, although yellowfin tuna,* T. albacares, *and bigeye tuna,* T. obesus, *were the preferred target species. Bycatch also included swordfish, large sharks, pelagic rays and other pelagic fishes, other tunas, and marine mammals.*

In the Northwest Atlantic, pelagic pair trawlers have targeted albacore and other tunas and swordfish, *Xiphias gladius*, in this mid-water fishery.

With the U.S./Canada, or Hague Line, boundary decision of 1984, the U.S. swordfish harpoon fishery effectively disappeared owing to loss of fishing grounds. U.S. swordfishermen investigated alternative fisheries, and a small number began to target swordfish with a new gear type, the pelagic pair trawl, in 1991. Three pairs of vessels targeted swordfish during this first season. In 1992, two additional pairs entered the fishery. However, swordfish regulations in 1992 precluded continued targeting of swordfish and mandated observer coverage. This paper summarizes the catch, bycatch, and fishing methods from pelagic pair trawl trips observed in October and November 1992 off the U.S. mid-Atlantic coast.

Materials and Methods

Observers were placed on pelagic pair trawlers selected by NOAA's National Marine Fisheries Service (NMFS) during the period from 14 October to 19 November 1992. To maximize observer coverage of this pair trawl fleet, observers were placed on one vessel of a pair, and coverage was waived for the second vessel for that trip. Although this fishery is generally conducted from late June to mid-November, observations and data reported in this paper cover only the latter part of the 1992 fishery.

Observers collected vessel, economic, gear, catch, bycatch, and discard data on each trip. Additionally, location, effort, environmental, and complete catch data were recorded for each tow retrieved and processed aboard the observed vessel. As time permitted, length and sex data were recorded for individual animals, and biological samples (gonads, hardparts for ageing, stomachs, tissue samples, etc.) were collected. For tows retrieved and processed by the nonobserved vessel of the pair, only tow location, effort, environmental, and catch data for the retained species were recorded. Hence, no discard data were collected for tows processed on the nonobserved vessel.

Results

The nine observed trips ranged from 4 to 11 days in duration with an average of 7 days. Vessels departed from ports in southern New England and New York. Fishing occurred primarily in the mid-Atlantic region near Hudson Canyon with a smaller amount of effort as far south as Norfolk Canyon (Fig. 1). Bottom depths fished were predominantly from 433 to 814 m (237 to 445 fathoms), but ranged from 137 to 2,597 m (75–1,420 fathoms). Limited fishing effort south of Hudson Canyon occurred in November as tuna became more dispersed and the weather deteriorated.

Pelagic pair trawl fishing operations were conducted at night with an intended target species of bigeye tuna, *T. obesus*. Bigeye tuna was preferred since it was more highly valued than other tuna species caught. Pelagic nets were towed for an average period of 4.4 hours at speeds ranging from 3.2 to 4.8 knots (4.0 knots average). The size of the net, vessel, and horsepower, and the swimming capabilities of the target species likely dictated the observed tow-

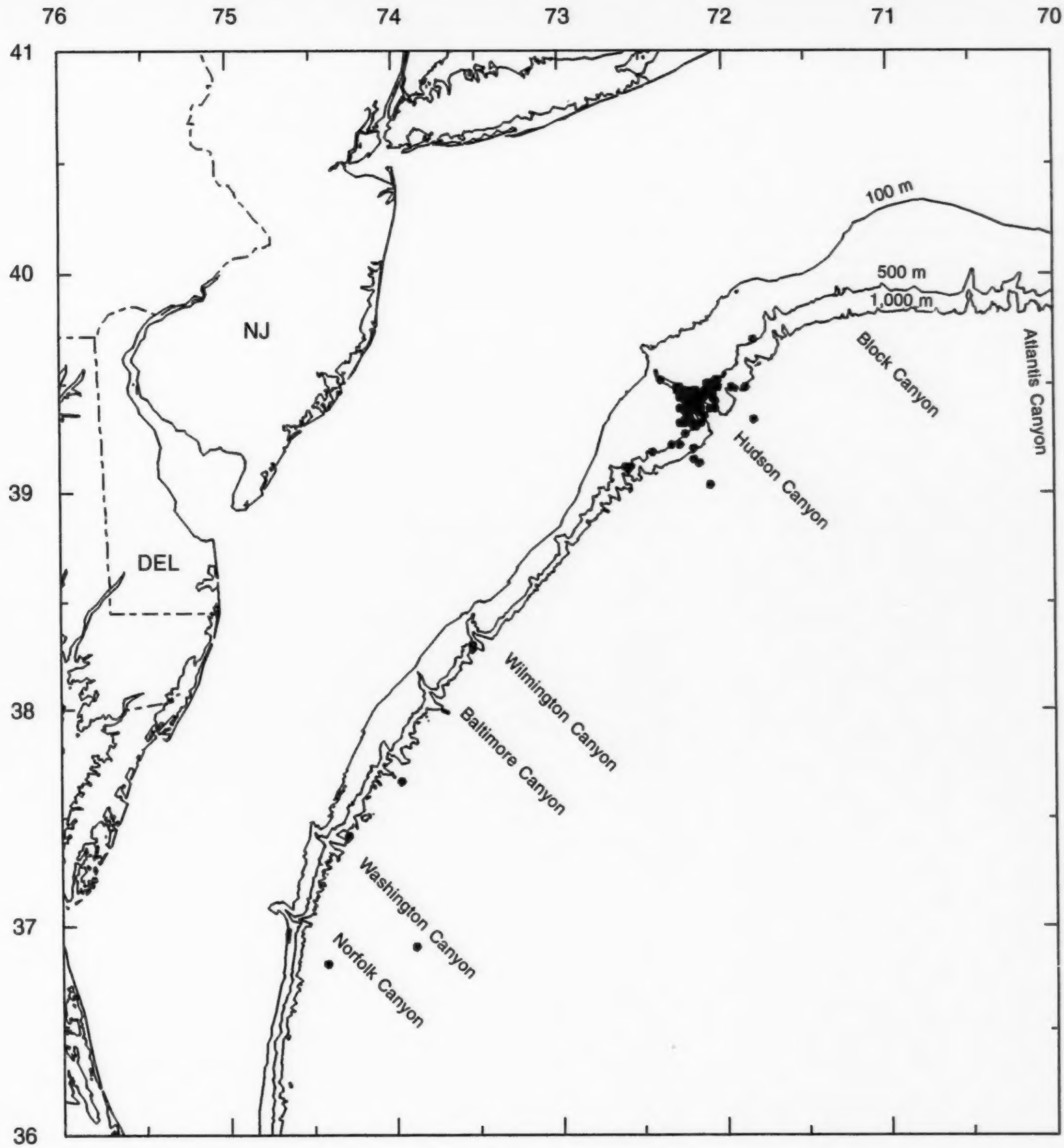

Figure 1.—Distribution of all tows from observed pelagic pair trawl trips, Oct.–Nov. 1992.

ing speeds. One vessel of the pair typically retrieved the net and processed the fish. Pelagic pair trawl fishermen generally alternated processing the catch between the two vessels each tow.

Two different pelagic nets, Le Drezen[2] (French manufacture) and Shuman (American manufacture) were used by the vessels. The vessels towed these trawls about 183 m (100 fathoms) apart with net openings ranging from about 23 to 55 m (13–30 fathoms) depending

[2] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

on the net used (Anonymous, 1991; Venturo, 1993). Most observed vessels utilized a transducer, or net sounder, placed on either the headrope or footrope to determine the depth and opening of the net. While fishermen believe that net depth recorded by the transducer is important to fishing success and marine mammal avoidance (Venturo, 1993), only limited headrope, or gear, depth data were collected in 1992. With the transducer, fishermen are able to adjust headrope depth during a tow and from tow to tow. Headrope depths observed ranged from 9 to 55 m (5-30 fathoms) below the surface.

Observers were placed aboard 9 of the 11 vessels operating in the fishery in 1992 and recorded vessel characteristics for the five pairs involved. One pair included three vessels, with one vessel alternating from trip to trip with the two other vessels. A majority of the vessels were <10 years old and ranged in length from 23 to 27 m (74-87 feet). Vessel size appeared to be well matched for most of the pairs; however, horsepower between vessels of a pair was more disparate, e.g. 850 hp versus 675 hp. Dissimilar vessel specifications may have been otherwise compensated for but not recorded by observers.

A total of 101 pelagic pair trawl sets was made during the 9 observed trips with 48 tows observed. From 1 to 3 tows were made each night. The remaining 53 tows were retrieved by the nonobserved vessel of the pair, and thus not all catch was directly seen by the observer. Since pair trawl captains must work in close cooperation, catch information was usually passed via radio to the nonretrieving vessel. This timely transfer of catch information allowed the observer to record all retained catch but not discarded catch. Due to close proximity of the vessels during trawl setting and retrieval, observers often reported they could see much of the catch as it was being dumped out of the net onto the other vessel for processing.

In addition to pelagic pair trawl fishing, three vessels fished with bottom trawls during the day for anglerfish, *Lophius americanus*; squids; silver hake, *Merluccius bilinearis*; and scup, *Stenotomus chrysops*. This bottom fishing was not done in a paired configuration. A total of 46 otter trawl tows were made with 38 tows (83%) observed.

Albacore, yellowfin tuna, *T. albacares*; bigeye tuna, and swordfish were the primary species caught and landed (Table 1) from pelagic pair trawl operations. While most captains intended to target bigeye tuna owing to its higher value, albacore was the predominant species caught (70%). Small amounts of bonito, *Sarda sarda*; mako shark, *Isurus* sp.; and little tunny, *Euthynnus alletteratus*, were also retained. Tuna species were landed both dressed (headed, gutted, and tailed) and round, while all landed swordfish were dressed.

In accordance with 1992 swordfish regulations, each vessel was allowed to retain and land two swordfish per trip. Fifty-three swordfish were caught on the observed trips with 15 retained and 38 discarded. Of the discarded swordfish, 18 were released alive, 15 of which were tagged. The two-fish retention regulation resulted in highgrading, or upgrading, of swordfish on two observed trips. Highgrading typically involves discarding processed/stored fish to replace them with larger fish or species of a higher value later in the trip.

Table 1.—Retained and discarded catch from observed pelagic pair trawl tows, Oct.–Nov. 1992.

Species	Round weight (kg)	Average round weight/fish (kg)
Retained catch		
Albacore	27,717	21
Yellowfin tuna	5,433	24
Bigeye tuna	3,668	76
Swordfish	1,684	112
Bonito	9	5
Other pelagic fishes	3	—[1]
Subtotal	38,514	
Discarded catch		
Swordfish	1,170	
Albacore	1,271	
Hammerhead shark	295	
Blue shark	91	
Myctophidae	56	
Little tunny	48	
Fish unspecified	26	
Yellowfin tuna	18	
Roughtail stingray	18	
Angel shark	7	
Atlantic torpedo	5	
Loligo squid	4	
Cownose ray	2	
Louvar	2	
Jellyfish	1	
Nmeichthyidae	—[1]	
Subtotal	3,014	
Total observed catch	41,528	

[1] Dash = <1 Kg.

Discarded bycatch (excluding marine mammals) included swordfish, three tuna species, three species each of sharks and rays, Myctophidae, squid, *Loligo pealei*; unspecified fish, louvar, *Luvarus imperalis*; jellyfish, and snipe eels (Nemichthyidae) (Table 1). A total of 12 marine mammals were caught on four observed trips (Table 2).

Owing to night fishing operations and because marine mammals were not always brought on board, species identification and determination of condition were difficult. For example, one tow with three unidentified marine mammals was released in entirety in the water since one of the mammals was believed to have been alive. Atlantic pilot whales, *Globicephala melas*, were observed taken in the Bay of Biscay pair trawl fishery on one 15 day trip (Collet[3]). No sea turtles or sea birds were observed in the 1992 catches.

Discussion

Since the nine pelagic pair trawl trips observed in 1992 covered only 20% (about 1 month) of the 5-month fishing season, these observations provide a partial spatial and temporal characterization of the pelagic pair trawl fishery. Extrapolation of these data is not possible since the total number of 1992 pelagic pair trawl trips is unknown. However, the fishery was reclassified to a Category I fishery under the Marine Mammal Protection Act Exemption Program in mid 1993 based on preliminary 1992 observer data. This classification mandated specific marine mammal reporting and observer coverage. Additional vessels participated in the

[3] A. Collet, Musée Oceanographique, Port des Minimes, 17000 La Rochelle, France. Personal commun.

Table 2.—Marine mammals caught incidentally in observed pelagic pair trawl tows, Oct.–Nov. 1992.

Species	Number caught	Status: Alive	Status: Dead	Status: Unknown
Bottlenose dolphin	4		4	
Risso's dolphin	1		1	
Saddleback dolphin	3		3	
Unidentified dolphin	4	1	1	2
Totals	12	1	9	2

fishery in 1993 when word of the fishery spread throughout the fishing fleets.

Acknowledgments

We would like to thank the pelagic pair trawl captains and the net manufacturer, Paul Shuman, who have provided information and specifications on the gear utilized in the fishery. Additionally, we are grateful to the observers for their efforts to sample and record every animal caught.

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Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

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Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

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Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

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In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

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Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

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